Background Reading Material

IAS Training Programme
"Energy & Development"

September 12 - 16, 1994

Tata Energy Research Institute
Darbari Seth Block
India Habitat Centre, Lodi Road
New Delhi 110 003

EXTERNAL FACULTY

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Mr Prabir Sengupta
Senior Fellow

Mr L R Suri
Senior Fellow

Dr V V N Kishore
Senior Fellow

Dr Ajay Mathur
Fellow

Mr P V Venkataramana
Research Associate

Mr A N Chaturvedi
Senior Fellow

Dr Uma Datta
Research Associate

Programme Schedule

Training Programme for I.A.S. Officers on Energy & Development
September 12-16, 1994
India International Centre, 40 Max Mueller Marg,
Lodhi Estate, New Delhi - 110003 (Conference Room no. 2)

Monday, September 12 1994

0930-1045	Registration and Introduction
1045-1100	Refreshments
1100-1230	Energy in India - Ms Leena Srivastava, TERI
1230-1330	Lunch
1330-1430	Coal Sector - Mr R K Sachdev, Adviser, Ministry of Coal
1430-1445	Refreshments
1445-1545	Hydrocarbon Scenario in India - Mr Prabir Sengupta, Senior Fellow, TERI
1545-1645	Power Sector - Generation, Development and Environmental issues - Mr L R Suri, Senior Fellow, TERI

Tuesday, 13 September 1994

0930-1030	Renewables: Scope and Prospects - Dr V V N Kishore, Senior Fellow, TERI
1030-1045	Refreshments
1045-1145	Renewable Energy: Economics Dr V V N Kishore (contd)
1145-1245	Power Sector: Demand Side Management - Mr S Ramaswamy, Energy Economist, EMC

1245-1330	Lunch
1330-1700	Visit to Gual Pahari

Wednesday, September 14, 1994

0930-1030	Energy Use in Indian Industry - Mr K P Nyati, Adviser, CII
1030-1045	Refreshments
1045-1145	Power Sector Liberalisation - Dr Djamal Mostefai, World Bank
1145-1245	Energy use and Economic growth in developing countries - Dr Ananta Bhattacharya, Adviser, ONGC
1245-1330	Lunch
1330-1430	Montreal Protocol - Dr Ajay Mathur, Fellow, TERI
1430-1445	Refreshments
1445-1700	Roundtable discussion: Issues in commercial energy supply Discussants: - Ms Gayathri Ramachandran, Joint Secy, Min. of Power - Mr R K Sachdev, Adviser, Ministry of Coal - Mr Prabir Sengupta, TERI

Thursday, September 15, 1994

0930-1030	Sustainable development - Mr Hans-C Von Sponeck, Resident Representative, UNDP
1030-1045	Refreshments

1045-1145	Energy Use in the Transportation Sector Impacts - Mr V A Parampil, Adviser (Transport), Planning Commission
1145-1245	Land and Watershed Management - Prof. Kanchan Chopra, Institute of Economic Growth
1245-1330	Lunch
1330-1430	Domestic Energy Use - Mr P V Venkataramana, TERI
1430-1530	Environmental Economics: An Introduction - Prof Pulin Nayak, Economic Adviser, Planning Commission
1530-1545	Refreshments
1545-1700	Roundtable Discussion: Issues in Energy Efficiency and Conservation Discussants: - Prof. Geetam Tiwari, IIT, New Delhi - Mr Raghuraman, Secretary General, ASSOCHAM - Mr Jitendra Das, Exec. Director, PCRA

Friday, September 16, 1994

0930-1030	Energy-Environment Interface in India - Dr Dilip Biswas, Chairman, CPCB
1030-1045	Refreshments
1045-1145	Afforestation for Wasteland Development - Mr A N Chaturvedi, Senior Fellow, TERI
1145-1245	Energy Pricing in India - Dr Uma Datta, TERI
1245-1400	Lunch
1400-1500	Films
1500-1530	Refreshments
1530-1700	Course Evaluation

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COAL INDUSTRY IN INDIA - DEVELOPMENT ISSUES

- R.K. Sachdev*

1.0 Indian Coal Industry - An overview :

1.1 Coal is India's most abundant source of energy currently meeting over 60 percent of the country's primary energy requirement and will continue to be the main source of energy for at least next 50 years. Sustained development of all facets of the coal industry is, therefore, imperative for overall economic development of the country. Two decades after the planned development of the coal industry in the nationalised sector, it is time to take stock of the situation, as how to consolidate the gains made so far and how to overcome various deficiencies and shortcomings that still exist.

1.2 India's known coal resources have been assessed to be around 197 billion tonnes. These are enough to sustain an annual production level of around 550 million tonnes well beyond the 21st century. An investment to the tune of about Rs. 16000 crores (US $ 5.3 billion at current exchange rate) covering new projects, existing mines and other infrastructure has been made in the nationalised coal sector during the period 1973 to 1993. The coal production which was about 77 million tonnes in 1972-73 rose to a level of over 246 million tonnes in 1993-94, registering an annual growth rate of 5.7 percent. Power utility sector is the single largest consumer of coal. Next to electricity, steel is the second and cement industry is in the third position. In 1993-94, the total consumption of coal was 255.76 million tonnes, of which 66 percent was consumed for electricity generation, 13 percent for steel making and 4 percent in cement industry. Balance 17 percent was consumed by thousands of other industries.

1.3 The coal based electricity generation capacity which was around 8000 MW in the year 1973, when the coal sector was brought under the State control, has grown to a level of over 50,000 MW which is 65 percent of the total installed capacity, the share of hydel being 28 percent, oil and gas 4.5 percent and Nuclear 2.5 percent. The coal based installed capacity is expected to go beyond 85,000 MW out of a total capacity of 1,40,000 MW projected for the year 2001-02. The electricity sector will, therefore, remain the largest coal consumer in future also.

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* **Advisor (Projects), Ministry of Coal**

1.4 The overall mix of different primary sources of energ has been as follows :

(percentage)

Year	**Coal& lignite**	**Oil**	**Gas**	**Hydro+Nuclear**
1970-71	62.9	31.1	2.1	3.9
1975-76	65.0	28.5	2.6	3.9
1980-81	63.9	29.3	2.2	4.6
1989-90	59.2	29.7	8.0	3.1
1992-93	62.1	27.2	7.6	3.1
1996-97	53.0	32.0	11.0	4.0
2009-10	51.0	33.0	11.0	5.0

Source : **(i)** Current Energy Scene in India - Compiled by Energy Management Division, CMPDI, Ranchi, June '1993.

(ii) Preliminary material on energy for 90's beyond Prospects, Reality & Challenges - Planning Commission, Sept.'93).

1.5 Growth in consumption of coal in different sectors is given below :

(million tonnes)

	1979-80	**84-85**	**89-90**	**93-94**	**Annual growth over 1979-80 (%)**
Steel	22.52	25.27	28.37	32.57	2.6
Power (Utilities)	34.86	64.35	115.12	165.21	11.8
Railways	12.53	9.53	5.73	1.93	-12.5
Cement	4.53	7.11	8.74	10.36	6.1
Fertilizer	2.11	3.89	3.97	4.96	6.3
Soft Coke/SSF	3.38	2.24	1.30	0.57	11.9
Others incl. captive power	28.85	31.59	38.68	40.16	2.4
	108.78	143.98	201.91	255.76	6.3

1.6 The indigenous coal production is, by and large, adequate to meet the overall demand of various consumers except the steel mills for which about 6 million tonnes of low ash coking coal is annually imported partly to meet the gap in domestic availability and partly for blending for quality improvement. Action has been initiated to gradually reduce the import of coking coal by increasing domestic availability for the steel plants.

1.7 Estimated consumption of coal for the various sectors of economy for the next 20 years or so has been projected as follows:

(million tonnes)

	1996-97	2001-02	2006-07	2009-10
Steel	42.0	44.0	45.0	45.0
Power	190.0	241.0	302.0	340.0
Others	86.0	111.0	153.0	175.0
Total	318.0	396.0	500.0	560.0

2.0 Growth Plan

2.1 The coal production which was 238 mt in 1992-93 is projected to go upto 308 mt by 1996-97, 396 mt by 2001-02 and about 560mt by 2010 AD. For meeting the projected coal demand of 318 million tonnes by the terminal year of 8th Five Year plan, a production programme of 308 million tonnes has been drawn which together with the drawal; from the pit-head stocks would be adequate to meet the projected demand. For achieving the targets of production plans have already been drawn up. Implementation of new projects together with coal production from the existing mines would be adequate to meet the coal demand of the Eighth Five Year Plan period.

2.2 Similarly for the terminal year of Ninth Plan i.e. 2001 - 02 when the demand of coal will be about 396 million tonnes, projects for meeting this demand have been identified and in some cases already planned. Projects for an ultimate capacity of about 70 million tonnes are under appraisal and scrutiny and are likely to be approved in the coming 2-3 years. To facilitate expeditious implementation of new projects about 30 "Advance Action" proposals covering initial activities like acquisition of land, rehabilitation of project affected persons and creation of initial infrastructure have already been sanctioned involving a capital outlay of Rs. 185 Crs. These proposals are geared to contribute the bulk of the incremental production during the Ninth Five Year Plan. Besides, coal companies within their delegated powers would be taking up schemes to yield additional production during the Ninth Five Year Plan.

3.0 Major Issues

Some of the important issues that need to be addressed to for achieving the growth plans envisaged are :

- **Mobilisation of adequate funds to finance the planned development.**
- **Improving operational efficiency, financial viability and market competitiveness of coal industry.**

- **Increasing production and productivity.**
- **Ensuring supply of proper quality coal to different consumers suiting to their requirements - Coal beneficiation.**
- **Increasing production of coking coal for steel plants.**
- **Private sector participation in coal industry.**
- **Environmental control measures in coal mining areas and**
- **Introduction of cleaner technologies.**

3.1 Mobilisation of funds

Govt. budgetary support which was as high as 98% of the total outlay till 1985-86 has progessively gone down to 8% during 1993-94. It will further go down to almost zero in next 3 years. **Public sector undertakings are being encouraged to rely more and more on internal generation and market borrowing.** There is a resource gap of the order of Rs. 5500 crores for the development of 8th Plan projects and 9th Plan new starts. Efforts are afoot to mobilise resources through multilateral / bilateral credits and as well as through internal generation by improving operational efficiency and financial viability of coal companies.

3.2 Improving operational efficiency and financial viability

In the context of liberalised economic scenario and that the import of coal is now under Open General Licence and import duty on non-coking coal has been reduced from 85% to 35%, the Indian coal industry has to face competition from the foreign coal exporters. **It is in this context, it becomes imperative for the coal industry to further improve its operational efficiency and produce coal of quality which has a demand in the market, if required by beneficiating it and at prices which are competitive.**

Rationalisation of manpower particularly in the two heavy loss making companies (BCCL & ECL) and proper utilisation of equipment in opencast and undergound mines thereby resulting in less investment for achieving the incremental coal production is of utmost importance for improving financial viability of Coal India Ltd. CIL has infact taken such measures which resulted in reducing the incremental investment per tonne of incremental production from Rs. 645 in 1989-90 to around Rs. 610 in 1993-94. CIL has over the years closed down 47 of its mines and further identified 11 uneconomic mines which may be phased out in next 3-4 years to cut down losses from such mines.

3.3 Increasing production and productivity

In order to meet the rapidly growing demand of coal in the past, mainly for the power sector, coal industry has given more emphasis to opencast mining to yield bulk coal production in a shorter time frame thereby increasing production from opencast mines from 18mt in 1973-74 to 172 mt in 1993-94. The productivity of opencast mines has also steadily increased and reached a level of over 4.00 tonnes per manshift at present. However, there is considerable idle excavation capacity averaging about 15-20% (rough estimate) of the overall available capacity which should be harnessed through improvement in management of operations including better workshop support, improved management of spares and timely rehabilitation of idle equipment.

Opencast mining, by and large, being fully mechanised the Indian coal industry has acquired excellent expertise in planning, designing, operation and management of medium to very large opencast mines. Besides wide range of earth moving machinery being used in these mines is of indigenous origin.

In the area of underground mining, however, production and productivity have not shown any improvement. Underground mines of CIL employing about 70% of the total workforce suffer from very low productivity of 0.55 tonne per manshift which has remained stagnant over the years. High wage cost without commensurate increase in production and productivity in underground mines has seriously impaired the financial health of coal companies. Public sector coal companies like other PSUs have come to be regarded primarily as a providers and protectors of employment leading to low level of productivity. This is a major factor in eroding their profitability. Absence of the linkage between wage and productivity and also of any reward and punishment system has brought down levels of performance. This calls for urgent remedial measure to improve the situation. Other major factors contributing to low growth in production and productivity in underground mines are existence of surplus labour, depletion of reserves in many of the old mines with no potential for reorganisation and poor utilisation of underground equipment. Lack of manriding facilities, poor ventilation, poor lighting and lack of essential infrastructural facilities in many of the old underground mines have further compounded the problem.

With a view to overcoming these constraints, actions have been taken to rationalise manpower deployment and introduce mechanisation in underground operations. A thrust has been given for replacement of manual loading by machines like Side Discharge Loaders (SDLs) and Load Haul Dumpers (LHDs). Similarly, production from mechanised longwall faces is also being augmented from the mines where the conditions are favourable. To augment underground coal production, it will be necessary to open up medium to large capacity underground mines particularly in Jharia and Raniganj coalfields, which are the main sources of coking coal and superior grade non-coking coal. This would require early establishment of mine entries by way of sinking of shafts and drivage of inclines. This continues to be a weak area in the industry.

3.4 Coal quality - need for washing

Indian coals as such are predominantly of high ash content. During mining of coal due to admixture of extraneous non-coaly material the ash content further goes up resulting in deterioration of the coal quality especially in opencast mining which contributes about 70 percent of the total production. **Supply of consistent and appropriate quality of coal is one of the most serious problems that Indian coal industry is facing today. In order to minimise quality complaints all coal despatches should be governed by bilaterally negotiated commercial agreements for coal supplies.**

High ash in coal, apart from causing excessive wear and tear to equipment of thermal power plants, leads to higher outages requiring increased quantum of repair and maintenance. High ash content also means more coal to be transported to generate the same energy, which increases transport costs and environmental pollution enroute. In this context , beneficiation of high ash coals is particularly relevant. Reduced ash content in the beneficiated coal would result in lower delivery cost per million kilo calories, reduced air pollution as well as solid wastes; better plant utilisation; and improved plant performance due to reduced outages. Beneficiation of coal will also relieve to considerable extent the strain on the railways and result in enormous savings in transport costs. Considering these aspects in the overall context of Indian economy, beneficiation (or washing) of non-coking coal for use in the thermal power stations has now been accepted as a general policy. **The extent of beneficiation required and the optimum level of ash in the clean coal will have to be decided keeping in view the factors like nature and quality of raw coal, distance of the power plant from the coalfield etc.** Major consumers particularly power utilities being the main beneficiaries must come forward and accept the burden of additional cost on account of washing of non-coking coal. Steel plants are already accepting the financial burden of washing of coking coal.

On the basis of an exercise carried out in 1988 it was decided that all coals that are to be delivered to the power utilities located over 1,000 km from the coalfields should be beneficiated to reduce the ash content to 34 percent from the level of 40 percent plus in the run-of-mine (ROM) coal. The washing plants under implementation will, therefore, reduce the ash to 34 percent level. Another exercise carried out recently revealed that power plants located more than 2000 Km from the coalfields particularly those sited at coastal locations would benefit if indigenous coal is washed to bring down ash content to around 20 percent thereby improving the gross calorific value to over 5700 Kcal/kg.

Out of five sanctioned non-coking coal washery projects with a total raw coal input capacity of 24 million tonnes, construction of one at Bina (Singrauli coalfield) is nearly complete and one at Piparwar (North Karanpura coalfield) is expected to be completed by 1995 end. Other three namely Kalinga (8 mt), Ananta (2.6 mt) and Bharatpur (2.6 mt) all in Talcher coalfields are yet to be taken up. Slow progress in setting up of washeries is mainly due to reluctance on part of the consumers to bear extra washing cost and also to some extent lack of financial resources with Coal India Ltd.

Although the Government has accepted the need of beneficiation of all coals, the major constraint now is that of financial resources for setting up of washeries. As a step in that direction private sector participation in setting up and operation of coal washeries has been allowed. **Coal India Ltd. have already identified a number of sites for setting up of washeries in private sector on Build-Own-Operate (BOO) basis. Global enquiry has been floated for inviting Indian as well as international companies to set up washeries under BOO scheme. There is an urgent need of quick decision for setting up of coal washeries with private investment both Indian and foreign.**

3.5 Coking coal supplies to steel plants

The demand of washed coking coal for the integrated steel plants in recent years is far outstripping the indigenous supply, both in terms of quantity and quality. The existing washeries most of which are old, were designed to process raw coking coals having ash upto 25%. **The raw coal feed to the washeries, over the years, has undergone a gradual deterioration in quality due to : a) depletion of originally linked sources; b) introduction of large scale opencast mining in shallow areas originally developed by underground mining.** Coals now being supplied are of higher ash content and poorer washability. Due to this the utilisation of washeries is low because of limitations imposed by middling and reject circuits; resulting in reduced availability of washed coking coal as well as its higher ash content. Steel sector has to be supplied with washed coking coal with an ash content of 17±0.5 percent. However, the average ash content of washed coal supplies was about 20 percent in 1992-93. The modernisation of washeries taken up since 5 years back is not yet complete. **Early completion of on-going modernisation works in the existing washeries has to be ensured so as to supply the required quality of coal to steel plants. Raw coal availability is to be improved through close monitoring of various coking coal projects which are already under implementation. New washeries under construction and planned are to be expeditiously completed.**

Of the 46mt of "coking" coal being produced annually, only 50% is being used in the metallurgical sector. The remaining is of low volatile medium coking type which at present does not find use for steel making and is not being washed. Recent tests carried out by Central Fuel Research Institute and Research and Development Centre for Iron & Steel have demonstrated that these coals can be used in blend with other high volatile coking coals after washing to 18% ash level. **Expeditious action has to be taken in setting up of additional washery capacity to wash these coals for its eventual use in steel plants. Opportunity of private investment for establishing the new washery capacity for washing these coals should be availed of so that these coals can straight away be washed and supplied to steel plants.**

These steps when implemented can gradually reduce the import of coking coal by the steel plants to about 2 million tonnes by the year 2001-02 from a present level of about 6 million tonnes after taking into account the increased demand of steel mills in that year.

3.6 Private sector participation in coal industry

Recognising the constraints of resources faced by public sector coal and lignite companies for meeting increased demand of coal particularly for the private sector power stations, Govt. have by amending Coal Mines (Nationalisation) Act, 1973 in June, 1993, allowed development of coal mines in private sector for companies engaged in a) production of iron & steel, b) generation of power and c) washing of coal obtained from a mine. A number of power generating companies have already been given clearance to develop coal mines for captive use for a total generating capacity of about 13,000 MW requiring about 52 mt of coal. More such proposals are under consideration. In order to encourage larger scale of participation of private sector, Indian as well as foreign, broadening of the scope of private participation in Indian coal mining through further liberalisation has been suggested particularly by major consumers.

3.7 Environmental concerns

The most serious environmental concerns being faced by the Indian coal mining industry today are linked with the increasing emphasis on opencast mining. **These are degradation of land and shifting of people affected by the projects. Environmental problems in coalfield areas have further been compounded by past mining leading to land degradation and extensive damage to the overall environment in the mining areas.** About 18,000 hectares of the land has been rendered derelict due to coal mining operations in the past resulting in fires, subsidences, open excavations and waste dumps.

Currently the coal industry is rendering about 500 hectares of land biologically unproductive every year. It is anticipated that land degradation will rise to about 1500 hectares a year by the year 2001-02 AD. This degraded land needs proper rehabilitation. Another factor is the effect of mining in forest areas. Fairly large tracts of forest in North Karanpura, Ib valley, Talcher, Singrauli, Korba, Wardha and Godavari valley coalfields will be affected as a result of large scale opencast mining in these areas. Due care will have to be taken to ensure adequate compensatory afforestation as well as restoration work.

India with a very high density of population is seriously disadvantaged in acquiring large tracts of land required for opencast mining with the concurrent problem of resettlement and rehabilitation of people. Though, at present there is a rehabilitation package to resettle the displaced persons, there is lukewarm response from the land oustees as this package does not offer employment to one and all.

In order to provide effective rehabilitation and re-settlement (R & R) the guidelines established by the World Bank include :

- **Adequate compensation for lost assets.**
- **Assistance with relocation and support during the transition period and**
- **Assistance in re-establishing former living standards.**

The guidelines further emphasize that the project design should minimise the need for involuntary resettlement and that project should ensure that those who have to move benefit from the project that displaces them. **The objective is to provide means to improve their standards of living.**

Other environmental problems which have roots in past un-scientific mining in the Jharia and Raniganj coalfields are problems of fires in Jharia and surface subsidence in Raniganj. Efforts have been going on to deal with the fires and such efforts have helped in checking the spread to some extent and also in controlling some 5 or 6 fires. A comprehensive diagnostic study to deal with the fires in Jharia has been undertaken under IDA assistance. The problem of subsidence in Raniganj coalfield is equally serious. Some 38 places have been declared unsafe because of lack of precise details of underground worked out areas beneath these places. Over 45 occurences of subsidence have taken place in last 15 years seriously affecting the population living in these affected areas. Efforts have been going on to stabilise the underground goaves with hydropneumatic stowing of sand. But due to slow speed the efficiency of the technology is yet to be fully established. **There is a need to develop an appropriate technology for dealing with this problem.**

3.8 Clean coal technologies

At present India has over 50,000 MW of installed coal based generating capacity and another 35,000 MW is proposed to be added by the end of Ninth Plan period. The conversion efficiency with pulverised coal fired system is around 32% on the average with little potential for further improvement. It is in this context Govt of India have setup Technology Mission on Clean Coal Technologies which are more efficient with high ash coals and will improve the productivity of existing thermal power plants. The various components of the programme comprise gasification, pressurised fluidised bed combustion, coal beneficiation for slurry formulation and its combustion. **The Technology Mission is proposed to be implemented through demonstration plant on i) Integrated Gasification Combined Cycle (IGCC) , ii) Pressurised Fluidised Bed Combustion (PFBC) and iii) Coal Beneficiation and Slurry Combustion (CBSC).** The time frame for these programmes is likely to be 5-6 years and the fund requirement is estimated to be around Rs. 500 crs. A site for IGCC demonstration plant with a power generation capacity of 45 MW has already been finalised. This programme is being pursued by Council for Scientific and Industrial Research (CSIR).

Until such time, these clean coal technologies are demonstrated and commercialised, beneficiation of coal and fluidised bed combustion are the available options for improving combustion efficiency as well as environment. **Beneficiation of coal will reduce carbon dioxide and sulphur dioxide emissions per KwHr due to improved combustion of coal and help in reducing environmental pollution at the power station end.** Fluidised bed combustion for utilisation of high ash Indian coals as well as the middlings and rejects from the beneficiation plants is also contemplated. Presently there are over 100 FBC boilers of various capacities operating in India of which many boilers are of indigenous design. Most of these are for process steam; some are being used for captive power generation as well.

Seperate centres with networking facilities to have access to cleaner technologies from within and out side the country covering identification, acquisition, development and promotion of cleaner technologies are required to be setup with a view to reducing the green house gases and to have cleaner environment.

4.0 Summing up

Coal is very vital for India's economic progress as it will continue to provide a dependable, economical and sustained source of energy as well as chemical feed stock for many years to come. Future growth and development of indigenous coal industry will be influenced by number of factors hitherto not faced by the industry. In order to meet these challenges the industry will have to re-orient its internal operations as well as external policies so as to adjust itself to the changing market scenario. Public Sector coal companies will no doubt through their prudent professional and business oriented approach will be able to meet these challenges. Some of the tasks before the coal industry are - increasing production, productivity, economic viability and meeting the consumers requirement in qualitative and quantitative terms keeping in view the long term objective of environmentally sound sustainable development.

Hydrocarbon Scenario in India

by

Prabir Sengupta

Tata Energy Research Institute
New Delhi

September, 1994

Hydrocarbon Scenario in India

Prabir Sengupta

Oil and Gas Production

The prognosticated **geological resources** of hydrocarbons in India are now estimated at around 21 billion tonnes of which about 60% are in offshore areas and the balance are in onshore basins. However, only about 25% of the ***geological resources*** has been upgraded to ***geological reserves*** through exploration efforts. The recovery factors from these fields vary from field to field and the total ***recoverable reserves*** from the geological reserve of 5.7 billion tonnes were estimated to be 1.124 billion tonnes at the end of the 7th Five Year Plan. Since about 421 million tonnes of oil had been produced cumulatively, the balance recoverable reserves at the end of 1989-90 stood at 703 million tonnes. This figure went up to 779 million tonnes in 1993. The growth in oil production and reserves are shown in Figures 1 and 2 respectively.

FIGURE 1

GROWTH IN OIL PRODUCTION

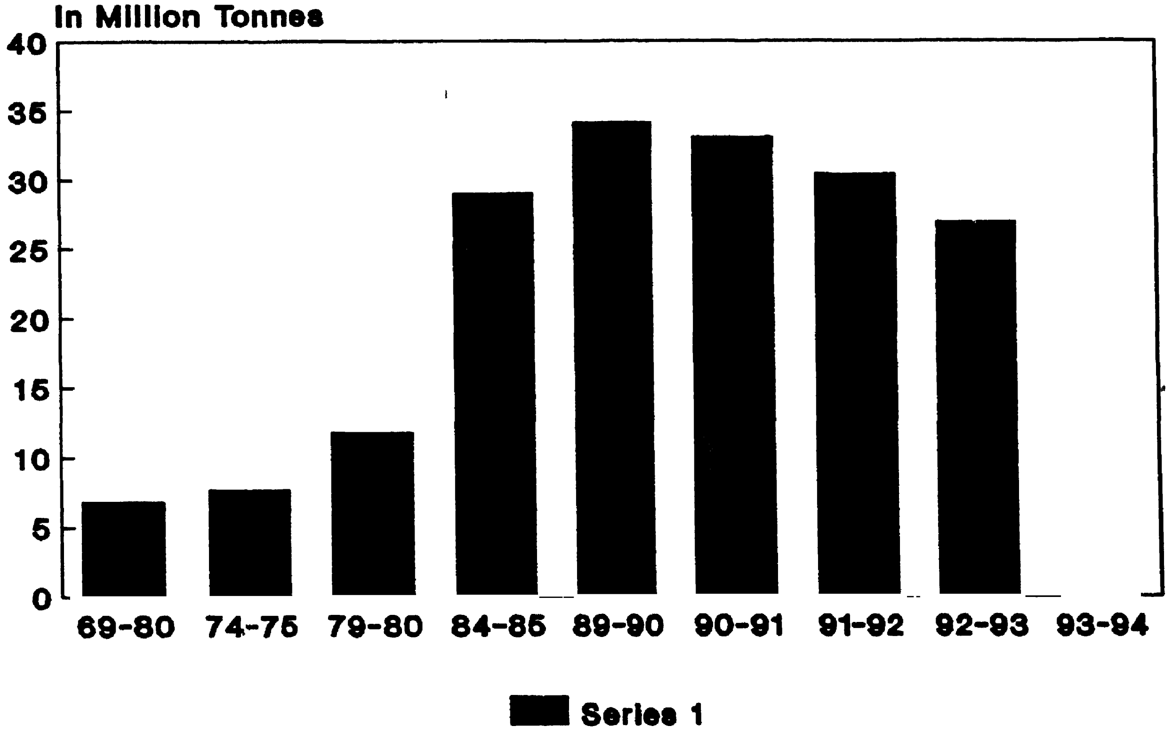
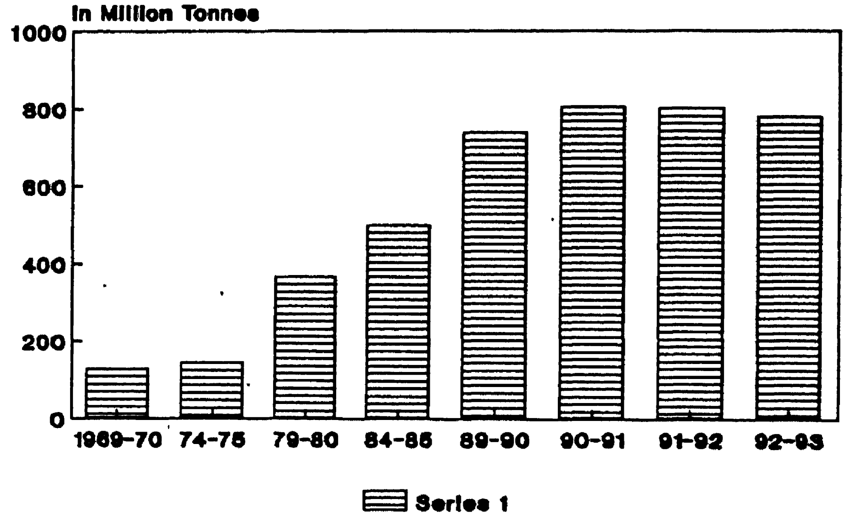


FIGURE 2

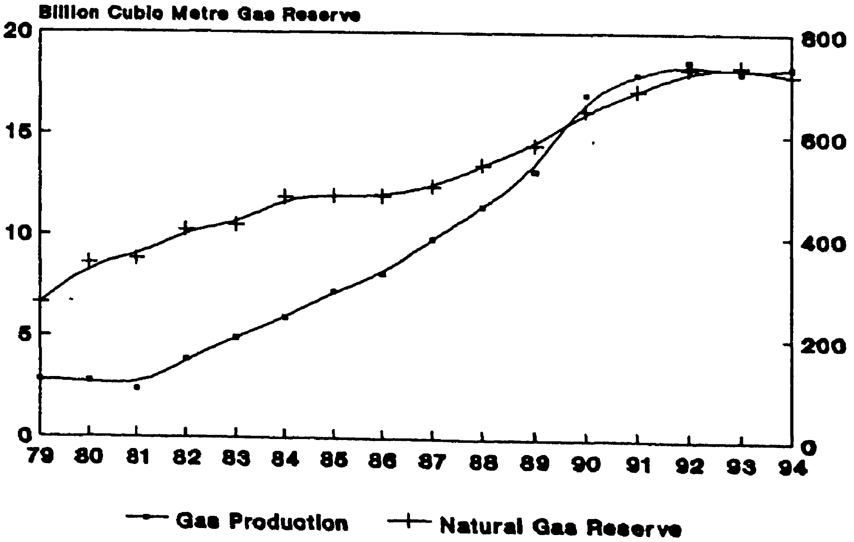
GROWTH IN BALANCE RECOVERABLE OIL RESERVES



Natural Gas production has been rising steadily since the beginning of 1980s. Apart from the associated gas that is produced along with crude oil and production of which has been increasing along with increase in oil production over the years, discovery of non-associated gas in offshore and onshore basins has led to growth in reserves and production of natural gas that is more than proportionate to growth in respect of crude oil. Thus, from a production figure of about 2.4 billion cubic metres in 1980-81, the production level has been around 18 billion cubic metres per year since 1991-92. Similarly, the balance recoverable reserves of natural gas went up to about 718 billion cubic metres in 1993 from the figure of around 350 billion cubic metres in 1980.

FIGURE 3

GAS PRODUCTION AND BALANCE RECOVERABLE RESERVE



An unfortunate aspect in respect of natural gas has been the flaring of associated gas. This has been due to lower than committed offtake by the existing customers like fertilizer plants and power stations and inadequate evacuation facilities from the oil fields to the consuming centres. During 1984-89 (the 7th Five Year Plan period), more than 40% of the total production of 60 billion cubic metres of gas was flared. The current level of flaring is around 20%. All flaring is targeted to be eliminated by 1996-97 by improved evacuation facilities and supply management.

Crude oil and natural gas production targets for 1996-97, i.e. the terminal year of the 8th Five Year Plan, were fixed at 50 million tonnes and 30 billion cubic metres respectively. In view of the delay in taking up new projects, the crude oil production in 1996-97 is unlikely to exceed 44 million tonnes.

Consumption and Imports

The growth rates of consumption of India have been higher than those of production. The annual average growth rate in consumption of petroleum products in India during 1984-1989 (the 7th Five Year Plan period) was 6.9% against the anticipated figure of 6.4%. The actual growth rate in the previous five years (the 6th Plan period) was lower at 5.4%. The currently projected growth rate during 1992-97 (the 8th Plan period) is also 6.9%. The rate of growth declined somewhat in the last two years to 3.4% and 3% in 1992-93 and 1993-94 respectively. The growth rate is around 6% in the first quarter of 1994-95. The past consumption pattern and the present projections in the Planning Commission of Government of India are give in Table 1.

Two products namely, kerosene and HSD, account for bulk of the petroleum product consumption in the country. Growth rates in consumption of these products are also higher than that for all products taken together. As a result, the share of these two products together will go up from less than 50% in 1984-85 to nearly 55% in 1996-97. However, due to the low growth rates in consumption in the first years of the 8th Plan, the total consumption in 1996-97 may be only around 75 million tonnes or so.

One of the most important characteristics of petroleum product consumption in the country is that it has acted as a "swing fuel". In other words, oil consumption has grown when other fuels like coal and electricity are not available. Thus, LPG and kerosene consumption in the domestic sector has increased when soft coke/electricity are not available. Diesel consumption has similarly grown at a rapid rate for electricity generation in the face of inadequate/erratic availability of electricity and for freight transportation because of inadequate growth in rail transportation. Besides, with a change in life style, there is a switch to petroleum fuels like LPG and greater use of MS. As a result, in spite of recommendations to the contrary, the share of oil in final energy consumption has bee growing over the years as can be seen from Table 2.

Table 1
Consumption of Petroleum Products

(in 000 tonnes

	84-85	89-90	Growth rate 1984-89 (%)	91-92	96-97 (Projected)	Projected Growth rate 1992-97 (%)
Light ends						
LPG	953	2268	18.94	2650	4037	8.78
MS	2084	3491	10.87	3573	7654	16.46
Naptha	3125	3350	1.40	3334	6334	13.70
Total L.E	6318	9412	8.30	9988	18522	13.15
Middle Distillates						
Kerosene	5959	8239	5.75	8396	12100	7.58
ATF	1336	1775	4.08	1530	2452	9.89
HSD	13696	20706	6.82	22679	32388	7.39
LDO	1198	1486	5.76	1472	1441	-.42
Total MD	22429	23948	6.29	34398	49005	7.34
Heavy Ends of which						
Fuel Oils	7944	8820	2.11	9168	8911	-.57
Luber and Greaser	664	700	6.88	1705	1335	-4.77
Total HE	10048	12199	3.96	12421	13842	2.19
Total	38795	54095	6.9	56807	81369	6.9

Table 2
Percentage share of different fuels in Commercial Energy Consumption

	1953-54	1960-61	1970-71	1980-81	1990-91
Coal	79.6	74.1	59.1	52.6	39.0
Oil and Gas	17.1	20.9	31.3	35.7	43.4
Electricity	3.3	5.0	9.6	11.7	17.6

The share of coal, whose availability is relatively much more comfortable in India, has steadily come down yielding place mainly to oil, nearly 45% of the total requirement of which was imported in 1991-92. This percentage has gone up to 60% in 1992-93. The Table below brings out the relation of total oil imports to total exports of the country.

Table 3
Oil Imports as a Proportion of Total Exports
(Rs. Million)

	Net POL Imports	**Total Exports net of POL exports**	**Net POL Imports as % total exports**
1970-71	1320	15300	8.6
1975-76	12420	40220	30.9
1980-81	52580	67030	78.4
1984-85	35270	99260	35.5
1989-90	56490	269850	20.9
1991-92	118240	426130	26.8

As a result of favourable prices of crude oil and petroleum products in the international market, the percentage has come down to 23.3% in 1993-94 from 26.8% in 1991-92.

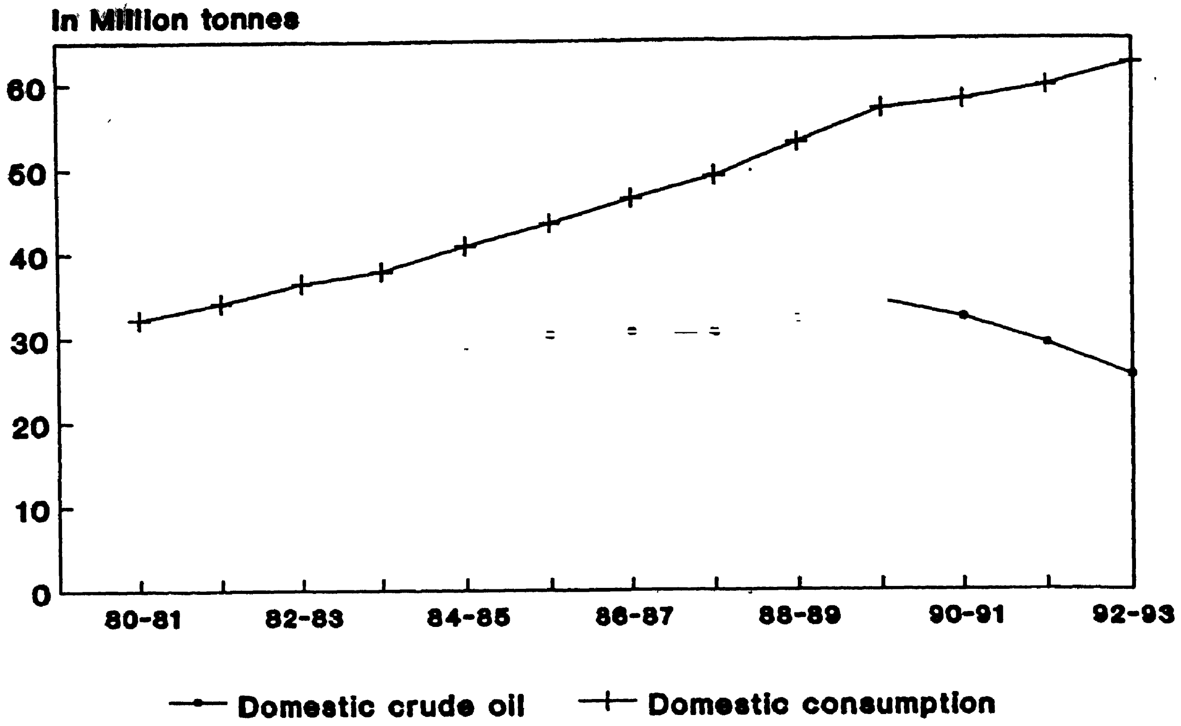
The import-dependence in respect of oil was about 50% in 1991-92. At the projected consumption of 81.36 million tonnes and the likely domestic crude oil production of about 44 million tonnes, the percentage of import dependence will remain at around the same level in 1996-97 entailing a heavy foreign exchange outgo. There is a distinct possibility of oil production reaching a plateau of around 50 million tonnes by the end of the current decade. This would only mean an increasingly higher import dependence on oil imports from the beginning of the next century.

The comparison between domestic oil production and domestic consumption is brought out in Figure 4.

As can be seen from the above, while the level of self-sufficiency reached a high level of around 71% at the end of the 6th Plan in 1984-85, the level came down to about 60% at the end of 7th Plan in 1989-90 and was only around 40% in 1992-93. The reduction in oil production in the last 2/3 years is due to planned containment of Western offshore production for improving the overall recovery from these fields and the trend is expected to be reversed from 94-95 onwards.

FIGURE 4

Domestic Oil Production and Consumption



Some Important Issues

It is clear that growth in oil production and consequent containment of the level of import dependence will depend upon new discoveries of oil and gas. The accretion of geological reserves of oil and oil equivalent of gas was a little over 1500 million tonnes during the 7th plan period. This was marginally higher than the target that was fixed. Accretion of 1400-1500 million tonnes would be necessary every five years to sustain an oil production level of around 50 million tonnes and around 100 million cubic metres of gas per day (The 1996-97 plan production target is 50 million tonnes of oil and 80 million cubic metres of gas per day). However, reserve accretion so far during the 8th plan period has been low and such five-yearly accretion targets are unlikely to be achieved during the 8th plan period unless some dramatic results in respect of oil discoveries are achieved in the next 2/3 years. Until the end of the 7th plan, 9 blocks had been offered to foreign parties for exploration. This did not lead to any hydrocarbon discovery. Thereafter, five more rounds of offers have been made until July, 1994 for exploration of around 130 offshore and onshore blocks by private parties. Going by the current responses, about 10/15 contracts may be signed by the end of 1994. It would appear that, in addition to relying on private efforts, more focused and intensified exploration efforts need to be undertaken by the two national oil companies, i.e. Oil India Ltd. and Oil and Natural Gas Corporation to improve new reserve accretion.

Natural Gas reserves perhaps permit a large increase in domestic gas production compared to oil production. Proposals for import of natural gas are also under consideration. Transport sector accounts for the largest share in petroleum product consumption. This is an area where substitution of oil by any other fuel is unlikely in the medium term. Greater use of natural gas will mainly lead to substitution of fuel oil and coal. The environmental advantages of natural gas are obvious, but increased use of natural gas through imports will depend upon the cost of imports vis-a-vis the cost of alternate fuel.

In this context, efficient use of oil becomes a matter of particular importance in the Country. The professed objective of containment of consumption of petroleum products by greater use of other fuels has not really been achieved. What is really required is appropriate pricing of different forms of energy encouraging a switch away from oil and improvement in supply of other forms of energy. Besides, the potentials of cost-effective energy conservation have already been identified for various spheres including for energy-intensive industries. Our success in realising such potentials will considerably help contain the rate at which the consumption of petroleum products will grow.

The other important issue that is emerging in the oil sector, as in the other sectors of the economy, is the extent of private participation. Oil exploration and oil production, oil marketing and oil refining are now largely being carried out by public sector oil companies. While attempts to involve private oil companies in oil exploration had been made since the beginning of the 1980s, private participation in marketing activities of select petroleum products is a very recent phenomenon. It is expected that there will be a significant presence of private parties in the oil sector in the coming years. This should help induction of both new technology and capital. However, the administered pricing regime today is based on a system of transfer prices from the production companies through the refining companies to the marketing companies, all in the public sector. Besides, petroleum product pricing is also based on a weighted average cost of crude oil reflecting the cost of imported crude oil as also the price being allowed to domestic oil producing companies. Such an administered pricing system will have to undergo major revisions if there is significant presence of private parties and if international prices are to be reflected in the domestic prices of different petroleum products.

Power sector - generation: Development & environmental issues

L R Suri
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ENERGY & DEVELOPMENT ISSUES IN THE POWER SECTOR

Generation, Environment and Development

1. Power shortages
2. Demand for Power and Planning for Power Development
3. Growth over various sectors. Per Capita Consumption
4. Resources for Power Development - Central & State
5. Delays in commissioning new plants
6. Financial viability of State Electricity Boards -
    - Commercial losses
    - Cost\unit of Generation & Supply
    - Realization - Electricity Pricing - Tariffs
    - Tariffs - Agriculture & Domestic
    - Losses in supply to agriculture and domestic sector
    - Rural Electrification
    - Subsidies
    - Receivables
7. Capital Structure of SEB's
    - Internal reasons . ROR
    - Loan and equity capital - State Govt loans
    - Market & Institutional Borrowing
8. Resources for Power Development

   Rate of return of State Government loans

   Repayment of loans
9. Operational Performance of Power Sector

   Forced outage, planned maintenance, availability. Partial outages, PLF
10. T&D Losses
11. Fuel Consumption - Efficiency of Generation

12. Sources of Power Generation

    Hydro, Thermal, Nuc Gas etc

    Gas utilization; fuel substitution

13. Pithead and load centre stations

14. 8th plan for Power Development

    Plan Priorities - Strategies for meeting demand.

    Regional Generation of Power

    Problem of coal supply, Pricing, Transport

    Problem of Plant & Equipment

    R & M & Uprating of Plant & Equipment

    Supply & Demand Management

    Efficiency improvement

    Improved Operational Performance

    Energy Conservation

15. Perspective Planning -

    9th and 10th Plan

    Planning Criteria: System Reliability

16. Environmental Considerations in Power Generation

17. Clean Coal Technologies

18. Captive Power and Cogeneration

19. Gestation Period of Power Projects

20. Privatization of Power Development

21. Non-Conventional & Renewable Sources of Energy Supply

22. Structural changes in the Power Sector

    Separation of Generation, Distribution and Rural Electrification

STATUS OF POWER DEVELOPMENT IN INDIA
(1992)

1. PRESENT POWER POSITION : The total installed generating plant capacity in the utilities at the beginning of the 8th Plan (31.3.92) was 69082 MW. This comprised 19189 MW Hydro, 48108 HW Thermal, and 1785 MW of Nuclear Plant (Table 1).

Table 1. POWER SECTOR OVERVIEW

	1960-61	1970-71	1980-81	1991-92
Installed Capacity	4653	14709	30214	69082
Hydro (MW) (%)	1917 (41.19)	6383 (43.39)	11791 (39.02)	19189 (27.78)
Thermal (MW) (%)	2736 (58 80)	7906 (53.74)	15753 (58.12)	48108 (69.64)
Nuclear (MW) (%)	-	420 (2.85)	860 (2.84)	1785 (2.58)
T&D losses	14.6	17.90	20.56	22.45
Sectoral Consumption (%)				
Domestic	10.7	8.8	11.2	16.1
Commercial	6.1	5.9	5.7	5.8
Industry	69.4	67.6	58.4	46.3
Agriculture	6.0	10.2	17.6	25.0
Other	7.8	7.5	7.1	6.6

The total generation of electricity during the year was 286711 MU. There was peak power shortage of 17.7% and energy shortage of 8.5% on all India basis in 1991-92. Region wise the peak load shortages varied from 32.4% in the Eastern region to 7.6% in the Western region and the energy shortage varied from 21.6% in the Eastern region to 8.3% in the North-Eastern region (Table 2).

Table 2 POWER SUPPLY POSITION IN THE COUNTRY

Region	1990-91 Peak load (%)	1990-91 Energy (%)	1991-92 Peak load (%)	1991-92 Energy (%)
Northern	- 11.9	- 5.4	- 19.6	- 8.0
Western	- 13.9	- 3.6	- 7.6	- 0.2
Southern	- 21.5	- 10.9	- 21.8	- 12.5
Eastern	- 27.5	- 18.5	- 32.4	- 21.6
North-eastern	- 3.6	- 4.6	- 17.2	- 8.3
All India	- 15.5	- 7.9	- 17.7	- 8.5

The shortages in energy and peak power supply resulted in frequent load shedding, serious frequency problems as well as wide voltage fluctuations. There have been a number of grid failure in the various regions causing brown outs and black cuts. The shortages are due to delays in adding new capacity, considerable time lag in stabilization of the newly commissioned units and sub normal performance of a large number of plants During the 7th Plan, the average annual rate of capacity addition was of the order of 4280 MW. The total capacity addition during 1990-91 and 1991-92 has however been 5803 MW for the 2 year period. About 4000 MW of Thermal Plant remains under stabilization. There is a shortage of at least 10,000 MW of installed capacity at present.

The share of hydel generation capacity which plays an important role in meeting the peak demands declined from 34% at the end of 6th Plan to 29% at the end of the 7th Plan and further to 27.8% at the end of 1991-92. The central share in the total installed generating capacity increased from 16% at the end of the 6th Plan to 26.1% at the end of 1991-92. The share of large pit head power stations increased progressively from 10% at the end of 6th Plan to 25% at the end of 7th Plan.

2. PERFORMANCE OF POWER SECTOR: The performance of the Thermal Power Plants in the country registered an overall improvement during the 7th Plan. The all India average plant load factor increased from 50% at the end of the 6th Plan to 56.5% at the end of the 7th Plan. This was mainly due to the introduction of large sized units in the system and the renovation and modernization programme of the small size units. The Plant performance in the Eastern and the North-Eastern region however, continued to be unsatisfactory. The T & D Losses in the power systems throughout the country continued to remain high at 22-23% during the 7th Plan period. These losses continued to be high due to low investment made on T & D facilities in different states and the extensive low tension distribution network in rural and urban areas. These factors have also contributed to the poor quality of electricity supply in many areas

3. FINANCIAL PERFORMANCE: The financial performance of the Power Sector has been a cause of extreme anxiety to all concerned. It is imperative that utilities generate adequate internal resources to be able to fully cover the fixed and operating costs including interest and other liabilities and have adequate surplus for funding their future expansion programmes. For this purpose, the State Electricity Boards are required to earn a return of not less than 3% on their net fixed assets. The all India average position in 1989-90 and 1990-91 was that this figure stood at (-)3.90 and(-) 3.96%

The major reasons for SEB's losses have been low agricultural and domestic tariffs and losses arising from rural electrification for which they are not adequately compensated The tariffs in all the states have remained well below the average cost of generation and supply. Against the average cost of 119 20 paise for generation and supply at consumers' end in 1991-92 the average tariff for agricultural sector was 15 8 paise. Similarly the average rate for supply to the domestic sector was 69.8 paise and the loss per unit sold to the sector was 49.40 paise The total revenue loss in 1991-92 of all the SEB's was 4498 crores during the year and the internal resources were (-)1684 crores A subsidy of about Rs 2000 crores per year was due to the SEB's from the state governments on account of loss for supply of power for R.E. and agricultural sector.

Apart form the rate of return and profitability the Electricity Boards are facing the liquidity problem as a result of their inability to recover dues from consumers In many SEB's the level of outstandings has already reached alarming proportions In return these undertakings have also been defaulting on payments to be made to central undertakings like CIL,NTPC,NHPC,BHEL etc. from whom they purchase coal, electricity and power equipment. They have also defaulted in payments due to the railways. There is thus a huge financial undiscipline in all the important infrastructural sectors of economy which are represented by these utilities.

Electricity supplied to the agricultural sector is unmetered. The low unmetered tariff charged on the sale of electricity to the sector has not only resulted in heavy financial losses to State Electricity Boards but also led to the wasteful use of electricity as well as water. There is no incentive for energy conservation. The State Electricity Boards suffered a loss of Rs.3800 crores during 1990-91 for supply of Electricity to the agricultural sector.

The R.E. program has resulted in an increase in T&D loss in the power sector due to extension of the L.T. Network in a sub-optimal manner. The T&D Losses on an all India level are of the order of 22-23 per cent. Of this total loss, about half is attributable to the rural electrification distribution network.

A rational tariff structure was to be evolved for the agricultural sector which would provide guidelines to the states and SEB's for subsidies to this sector. As an interim measure, it was decided that electricity will be sold to the agricultural sector at a uniform minimum rate of 50 paise per unit through out the country. This decision has however not been implemented so far. It is necessary that constitution of regional tariff boards to rationalize and suggest normative state and central tariff is expedited.

4. The 8th Plan: The demand for Power in 1996-97 as per the 14th Annual Electric Power Survey is shown in Table 3.The installed capacity at 44000 MW at a reasonably acceptable level of reliability -2% LOLP (Loss of Load Probability) and at the existing performance level of plant and equipment was assessed at 44000MW.

Table 3.DEMAND PROJECTION (14TH APS)

	1991-92	1996-1997
Peak (MW)	50431	73656
Energy (MUs)	284501	416274

Keeping in view the physical progress of the on going projects and the likely fund availability, the working group on power had recommended in 1991, an addition of 36646 MW at an outlay of Rs. 1,27,000 crores. With the commissioning of this capacity peaking shortage of about 15.3% and an energy shortage of 2.3% was expected. Based on optimization studies this capacity was subsequently reduced to 35000 HW giving reliability level of about 5% LOLP. The finally approved programme is shown in Table 4.

Table 4. CAPACITY ADDITION PROGRAMME DURING VIII PLAN (MW)

	Hydro	Thermal	Nuclear	Total
Capacity as on 31.3.92	19189 (27.78)	48108 (69.64)	1785 (2.58)	69082 (100)
Additions During Eighth Plan	9282	20156	1100	30538
Total Capacity on 31.3.97	28471 (28.58)	68264 (68.52)	2885 (2.90)	99620 (100)

The Plan provision now made is Rs. 79590 as indicated in Table 5. The outlay provided is expected to fully cover the requirement of all on going schemes which will yield benefits of 24,316 MW (8969 MW of hydro, 14247 MW of thermal and 1100 MW of Nuclear) during the 8th Plan. The outlay however hardly contains any provision for advance action for projects to be commissioned during 9th Plan. The funds for this purpose are proposed to be generated with-in the power sector by technical improvements and ratioalisation of tariff structure. The outlay for generation, including renovation and modernization programme is Rs. 51200 crores and transmission & distribution including rural electrification is Rs. 26280 crores

Table 5 OUTLAYS FOR POWER SECTOR

(Rs. crores)

	States	UTs	Centre	Total
Generation	24732.78	354.24	24337.13	49424.15
Transmission & Distribution	16782.41	1061.53	4436.81	22280.75
Rural Electrification	4000.00	-	-	4000.00
Renovation & Modernization	1225.74	13.40	537.30	1776.44
Miscellaneous	220.93	16.71	1870.34	2107.98
Total	46961.86	1445.88	31181.58	79589.32

As in earlier plans, the proportional outlay on generation is higher at 64% compared to T&D outlay of 33% against the desired lay out of 60 :40. The Physical progress of projects particularly Hydro Projects is such that benefits of about 3000 MW may not accrue in the 8th Plan.

5. **PLAN STRATEGY:** The power sector has to contend with rapidly rising demand, growing environment impacts and a major scarcity of resources for new investments. The basic thrust of the measures and the activities to be initiated during the plan would therefore be

i) To lay emphasis on improvement in the operation of the existing Thermal generation units and reduction in losses in the T & D system, improvement in the financial performance of State undertakings and expeditious project implementation to minimize cost and time over runs.

ii) Maximum utilization of existing facilities i.e. improvement in productivity of the existing plants. It has been estimated that by renovation and modernization of 201 units with total installed capacity of 19,990 MW, an improvement of 7% in PLf (from 45% to 52%) can be achieved. This is equivalent to 2650 MW of capacity addition.

iii) Residual life assessment and life extension. It is expected that about 500 MW of capacity every year could be made available from this.

iv) Uprating of 49 hydro power stations with installed plant capacity of 8839 MW yielding additional availability of 761 MW.

v) Improvement in PLf of Thermal Power Plants from 53% to 58% yielding a benefit of 6211MW.

vi) Improvement in peaking capability of Thermal Power Plants from 57% to 63% yielding a benefit of 5543 MW.

vii) Reduction of auxiliary consumption of Thermal Power Stations from 10% to 8.5% yielding a benefit of 1242 MW.

viii) Power System Improvement - Reduction of T & D Losses from 23% to 18% by increasing investment in T & D from 33% to 40% yielding a benefit of 4419 MW.

ix) Reduction in Peak load by demand management i.e. increase in the system load factor from 64.5 to 67.5% this yielding a benefit of 4643 MW.

X) Energy conservation in industrial, agriculture and household sector at 5% giving a benefit of 4145 MW.

These measures together would reduce the generating capacity need by about 20,000 MW as compared to capacity of 44,000 MW worked out on the basis of business as usual performance.

The power scenario with improved performance is depicted in Annexure 1 and the reduction in installed capacity due to improved performance in shown in Annexure 2.

6. DEMAND MANAGEMENT: Demand management is the deliberate influencing of consumers electricity demand to optimize overall system operation efficiency and cost of the power supply in the system. Load management includes load reduction as well as load shift The electricity demand imposed on the Indian Utilities normally exhibits a pattern of peak demand during a few hours in the morning and evening, a shoulder level during the day time and an off peak valley during the night

Load management options can be broadly grouped under three heads. a) administrative measures, b) pricing options, when prices are used to stimulate load management and c) technological options, where technology is used to reduce the demand In India, given the shortage situation, almost all the utilities have adopted a variety of administrative methods to manage the load on their systems. These include imposing power and energy restrictions, peak period restrictions, 'rostering' the supply to different feeders, staggering of working hours and staggering of holidays in industries etc Apart from these planned measures, there is also unscheduled load shedding. Though these administrative measures are relatively easy to implement they have certain negative implications for other socio-economic factors. For instance, the unscheduled load shedding and voltage fluctuations could result in production inefficiencies, production losses and damage sensitive equipment. In the management of load with pricing, time of the day tariffs are one of the pricing options that can be used to encourage the consumers to shift load from peak hours to off-peak hours. Under this method, electricity consumption during the peak hours is charged at a higher rate as compared to the electricity consumption during off-peak hours. The rationale behind the price differential between peak and off-peak hours is that the consumers using electricity during peak hours should pay both capacity and energy costs where as those consuming electricity during off-peak hours should pay only the energy costs. A number of SEB's have inverted block tariffs for domestic and commercial consumers. In this tariff structure, the lowest consumption block is charged the lowest rate and the rate increases as the consumption increases. The main objective behind this is to keep the rates lower for poorer consumers and to discourage high consumption of electricity. Since a major portion of the domestic consumption is for lighting purposes which coincides with the peak time the inverted block tariffs help in reduction of peak load. Studies indicate that maximum contribution to the peak load is from domestic and commercial sectors. Although their share of consumption of the yearly energy sales is of the order of 16% and 6% only, their share of contribution to peak load is of the order of 39% and 13%. There exists therefore a very strong case for substituting low efficiency incandescents with high efficiency flourescents, the criteria being that the existing lumen level is maintained. A new generation of compact fluorescent lamps has now been introduced in the Indian market. There lamps use only one fourth of the energy used by incandescents. As these lamps hold a lot of potential for the Indian lighting system but are costly, some of the utilities are thinking of leasing these lamps to the consumers.

The technological options in demand management are, conservation of energy, end-use efficiency, energy efficient Industrial processes, lighting and energy efficient appliances in domestic sector and energy efficient pump sets in agricultural sector.

7. RURAL ELECTRIFICATION: During the 7th Plan a target of electrifying an additional 1,18,101 villages and energizing 24 lakh pumpsets was fixed. Whereas pump energisation target was over fulfilled by energizing 25 lakh pumpsets, only 100000 villages were electrified. Although about 84% of the villages have been electrified, so far only about 27% of rural house-holds have been supplied with electricity. Provision of electricity for lighting in rural areas is essential not only to reduce the use of kerosine oil, but also to enhance the quality of life in the rural areas. It is also necessary for operating agriculture pumpsets to utilize available under ground water potential and replace diesel pump sets. The number of villages electrified in the state of Uttar Pradesh, Rajasthan, Bihar, West Bengal and Orissa is below 78%. The tampo of electrification in these states requires to be expedited.

8. **CENTRAL GENERATION**: The central share in the total installed generating capacity increased from 16% at the end of the 6th Plan to 26.1% at the end of 1991-92. The share of large pit head stations increased progressively from 10% at the end of the 6th Plan to 25% at the end of 7th Plan. Power Generation in the country is mainly the responsibility of the states, but with the financial crunch from which most of the electricity boards are suffering, some of them have tried to abrogate this responsibility to the central sector for construction of the load centre stations. Central sector generation was taken up in early seventies to supplement and not to supplant the states efforts of Power development. Generation at load centres should continue to be the responsibility of the states and the centre should confine its activities to construction of large regional pithead Thermal Stations and large regional Hydro Electric Projects.

9. **PRIVATE SECTOR PARTICIPATION**: In-order to cope with the heavy power shortages foreseen in the 8th Plan due to the huge resources crunch and to fall in line with the general global trend of conforming to market economy and privatization, the Government of India decided liberalization of the power sector to have an additionality of resources Accordingly the Electricity Supply Act was amended in 1991 and a number of incentives with reference to capital formation, rate of return, tariff and sale of power, higher rate of depreciation etc. were offered This has however not sufficiently attracted the private sector entrepreneur as they are not sure whether they will be able to sell all the power produced by them particularly at low load periods during the nights and whether they will get paid for the power supplied by them to the SEBs due to their critical financial position They also do not consider the 16% rate of return as adequate

10. ENVIRONMENTAL CONCERNS IN POWER GENERATION: Environmental concerns are high on todays policy agenda. The environmental and health related impacts of different energy systems particularly those associated with the production of electricity are emerging as significant issues for the coming decades. This interest is high lighted by the current debate about health effects of pollution, environmental damages due to acidification of forests and lakes, the concern about the safety of Nuclear Power Plants, radioactive waste management and the potential risks of global climate change induced by increasing atmospheric concentration of carbon dioxide and other green house gases.

Power generation can adversely affect land, water and air resources, depending on the type of power plant utilized. Power production and related activities are a major contributor to environmental pollution. According to recent estimates, these activities contribute approximately 80% of the total global emissions of carbon dioxide, a major green house gas considered to effect global climate change.

Coal presently is and will continue to be the mainstay of power generation in India. This places an enormous burden on the power sector for contributing emissions. Individual power projects have deleterious impacts, some times of considerable proportion on the local environment. In view of these considerations, environmental issues have taken major significance in planning generation expansion schemes. These issues call for identification of strategies to contain environmental emissions and require careful evaluation and integration from the initial phase of the project cycle.

RENEWABLE ENERGY TECHNOLOGIES FOR HUMAN SETTLEMENTS

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1. Introduction

In the last two decades, issues such as oil crisis, depletion of natural resources, environmental pollution, global warming, ozone depletion etc. have collectively contributed to the evolution and rapid acceptance of the concept of sustainable development. In essence, sustainable development means meeting the needs of the present generation without compromising the ability of future generations to meet their needs, and meeting human needs implies recognizing each person's right to a standard of living adequate for health and well being, including adequate access to food, clothing, shelter, medical care and necessary social services. Sustainable development is essentially a concept so far and it is generally agreed that it can not be achieved in a world where more than 1 billion people live in absolute poverty in urban slums and rural areas, predominantly in developing countries [1]. National and regional settlement systems, consisting of cities, small centres and rural settlements, are the framework within which economic activities operate, and hence management of human settlements in a sustainable manner becomes a central issue for achieving sustainable development. This involves several other concepts like sustainable land resource management, sustainable water management, sustainable waste management, sustainable energy management etc., the relative importance of each depending on the local situation.

Energy is a key input to development and energy use intensity has been considered as an index of development till recently. However, due to considerations like non-renewability and associated environmental degradation, several policy makers are now inclined to give due importance to energy conservation and renewable energy utilization, which are the two main pillars for sustainable energy development.

The various issues involved in utilization of renewable energy sources for sustainable management of human settlements forms the subject matter of this paper.

2. Energy Requirement for Human Settlements

For the purpose of examining human settlements from points of view of energy use, waste generation, resource availability etc., it is convenient to classify settlements as rural and urban and at different levels such as household, local, sub-regional etc. At the household level, energy is required for cooking, lighting, comfort conditioning etc., and the levels of energy consumption vary significantly depending on the climate, level of development, financial status of the occupants etc. In developed countries and in the cities of developing countries, energy spent on comfort conditioning can be far in excess of energy spent on cooking and lighting. The energy consumption indices for space heating are given in Table 2.1 for some selected countries.

Table 2.1: Energy Consumption Indices for Space Heating

Country	Watts per capita	Fraction of Total Domestic Consumption	kcal/person/yr
Canada	1276	0.73	9.6×10^6
USA	1030	0.64	7.7×10^6
Sweden	932	0.66	7.0×10^6
Denmark	876	0.71	6.6×10^6
UK	722	0.60	5.4×10^6
Germany	888	0.81	6.7×10^6
France	642	0.73	4.8×10^6
Italy	441	0.75	3.3×10^6
Japan	105	0.35	0.8×10^6
India (HP)	5.5	0.02	0.04×10^6

It is apparent that, while a large fraction (as much as 70%) is spent on comfort conditioning in the cold, western countries, regions in developing countries under similar climatic conditions spend only a very small fraction on space hating. There are 'order-of-magnitude' differences in absolute energy consumption figures also. For example, the per capita biomass consumption for cooking and other applications in the Asian region is about 1.2 kg per capita per day. This translates to about 1.6×10^6 kcal per capita, which is 6-8 times less than the per capita consumption of energy for space heating in developed countries. Similarly there are enormous differences in the consumption of electricity at household level for developing and developed economies. For example, 73.08% of all rural households and 24.8% of all urban households in India do not use electricity for lighting [2], whereas the households in developed countries rely only on electricity for lighting. Thus an important issue for sustainable management of households is to formulate norms for household energy consumption, based on energy requirements for a basic minimum comfortable living in the given climatic condition. A normative figure of 620 kcal (useful) per person per day exists for Indian conditions for cooking and water heating. The norms for space heating and lighting may be difficult to arrive at, but could be based on existing energy consumption figures with the most energy efficient devices available in the market. Once these norms are fixed, these can serve as the basis for sub-regional and national programmes to achieve sustainability.

In rural settlements, energy is primarily needed for irrigation pumping and agricultural operations like tilling, harvesting, winnowing, crop drying, refrigeration (cold storage) etc. In developing countries where irrigation facilities have not yet been developed fully, most energy is spent on irrigation pumping. In contrast, agricultural activities in developed countries seem to be requiring energy more for mechanized operations and post harvest operations. Energy requirements also vary from crop to crop and from region to region, and are directly proportional to the water requirements and depth of ground water. The water requirement for some of the crops in India are shown in Table 2.2

Table 2.2: Water Requirement for Different Crops

Crop	Water Requirement
Rice	1000-2500 mm per crop
Wheat	250-400 mm (North)
	500-600 mm (Central)
	10-15% more for Gujarat and Rajasthan
Cotton	400-500 mm near Delhi
Sugarcane	1400-3000 mm

The annual water requirement can be obtained by multiplying the above figures with the area sown and with the number of crops (seasons) per year. An estimated 44,000 MkWh of electricity is consumed annually for irrigation pumping in India. In addition, there are ove 5.5 million diesel pumpsets with a demand potential of 4.7 million tons of diesel annually.

In urban centres, energy is spent predominantly on transportation, civic amenities commercial centres and industry. These are the major consumers of energy in any country and as development continues, both the size and number of urban settlements increase, with consequent demand on high quality energy such as electricity and petroleum fuels.

At the national level, energy consumption figures vary greatly depending on the degree of development, measures adopted to conserve energy etc. The energy related figures for India for the years 1991-92 and estimates for 1996-97 are given below.

	1991-92	**1996-97**
Coal	229 million tons	308 million tons
Crude Oil (indigenous)	30.34 million tons	50.00 million tons
Crude Oil (imported)	24.00 million tons	13.32 million tons
Natural Gas	16 billion m^3	30 billion m^3
Electricity	312 billion kWh	
Generating Capacity	69082 MW	99620 MW

The per capita primary energy consumption for industrialized countries averages at about 5 TOE (tonnes of oil equivalent) whereas for most developing countries it is less than 0.2 TOE.

From the energy point of view, the problem of sustainable settlements management can thus be seen to be immensely relevant to developed countries whereas for developing countries the problem can be framed as that of improving the quality of life without a quantum jump in the consumption of non-renewable sources of energy.

3. Review of Available Technology Options

All renewable energy sources, except perhaps tidal and geothermal energy, are either directly or indirectly derived from sun. Direct utilization of solar energy has two routes, viz. solar photovoltaic and solar thermal. Solar photovoltaic systems, in which the basic components are solar cells, convert sunlight directly into electricity. On the other hand, solar thermal systems convert solar radiation into heat, which can later be utilized for any suitable end-use. A variety of solar collectors exist, such as the flat plate collectors, solar ponds, compound parabolic collectors, linear parabolic trough collectors, evacuated tubular collectors, point focus dish collectors and central receiver type systems. The use of these collectors for a very large variety of end-uses, such as water heating, space heating, drying, cooking, air conditioning & refrigeration, desalination, water pumping and power generation, has been amply demonstrated. Apart from these more modern, efficient methods of harnessing solar energy, there are several traditional methods, such as drying of clothes, sun-drying of crops, cottage scale food products, industrial products like china clay and production of solar salt, which are widely being practised in developing countries but are not accounted for in sustainable energy literature. If one can compute, for example, energy used in drying of clothes in washing machines in the developed economics, and compare it to the solar energy used in drying clothes in developing countries, it would be apparent that solar energy is already being used in developing countries in a significant manner.

Indirect means of using solar energy consists of biomass energy utilisation, hydropower utilisation, wind energy utilisation and ocean thermal energy conversion (OTEC). Hydropower, in both small and large scale utilization, is an established renewable energy source and the technology of utilisation is available widely. In recent years, wind has become established as a viable source of power generation through the now well known wind farm concept. Wind rotors have also been used for water pumping, battery charging and, in China, for space heating. Several designs of wind turbines, such as the 3-blade horizontal axis turbine, the vertical axis Savonious rotor, the vertical axis Darius rotor etc. are available for use in different wind regimes, for different applications and for different size ratings of machines.

Perhaps the largest share of utilisation of energy in the rural and semi-urban areas of developing countries comes from biomass. Biomass can broadly be classified as forest biomass, agro-residues and organic wastes. Forest biomass comprises of firewood (both logs and twigs), and wood wastes like bark and saw dust. A variety of non-fodder agro-residues like rice husk, rice straw, cotton stalks, jute sticks, mustard stalks, bagasse etc. are available in large quantities and are either used in rural households in a very inefficient way or left in the fields or simply burnt.

Organic wastes comprise of cattle dung, human excreta, municipal solid wastes, and effluents such as sewage and organic industrial effluents. Technologies for utilisation of biomass be broadly classified as thermochemical and biochemical. Thermochemical conversion of biomass consists essentially of three processes: pyrolysis, gasification and combustion. Fuel preparation methods such as cutting, pulverisation and briquetting may be needed for applications such as gasification. In recent years, gasification has re-emerged as an important technology especially in the Asia-Pacific region. Considerable progress has been made in design, development and testing of gasifier systems for both thermal applications and motive power applications in India. Gasifiers can be used for a variety of applications like large scale cooking, industrial process heat, irrigation pumping and power generation.

Biomethanation, also called anaerobic digestion, is a process in which organic residues can be treated to produce a high quality gaseous fuel, methane. This process has several big advantages like low energy requirements, simultaneous production of methane and fertilizer (for animal residues) and production of energy combined with effluent treatment (for industrial effluents). For digestion of cattle-dung, several models such as KVIC, Janata Deenbandu, Pragati etc. are available, though there is a good possibility of still improving and optimizing the rural, family size biogas plants. Reactors such as the anaerobic filter, fixed film reactor, UASB (upflow anaerobic sludge blanket) reactor etc. are commercially available at present for treatment of sewage, distillery effluents etc. and considerable amount of work has to be done to extend these technologies to other effluents. In comparison, technologies for utilization of solid and semi-solid wastes like MSW, food and vegetable wastes, wastes of food processing industries etc. are not readily available and have to be developed.

Not much efforts have been spent for utilizing aquatic biomass like water hyacinth. Considering that countries like India have enormous coastlines, growth and harvesting of marine biomass for energy generation should be an interesting prospect.

Production of liquid fuels such as methanol and ethanol from biomass either by fermentation processes or through thermochemical means is a very important area of R&D and pilot testing. Production of ethanol from sweet sorghum seems to be a viable method, but land availability had been identified as an important constraint.

Other technologies for renewable energy utilization are geothermal power generation, ocean thermal energy conversion and tidal power plants. Utilization of geothermal energy is significant in USA and Philippines, and the technology for power generation is based on what is known as the Organic Rankine Cycle turbine. The same principle is applicable for OTEC. Tidal power plants, though demonstrated in several places, are not available on a commercial scale.

4. Economic Considerations

The promise of renewable energy technologies is diminished many times because of the high initial costs required for installation. The economics of renewable energy utilisation is adversely affected by two factors: 1) the energy intensities of the resources are lower, requiring large physical areas and consequent high material cost and 2) there are continuous and large fluctuations in the availability of energy, which necessitates storage and/or stand-by source, which adds to the cost of the system. In the present, market based economies, any technology that does not have the edge of economic viability will not be accepted, and can only be superficially pushed by government subsidies and other incentives. There are, of course, several arguments in favour of renewable energy utilization from considerations of sustainability, environmental degradation etc., but these usually do not get translated to concrete actions or policies. Hence it is important to consider the economics seriously in order to establish the viability of renewable energy technologies. It has been shown that, in order to obtain an across-the-board comparison of various options, an end-us approach combined with the levelized annual cost (LAC) method, is highly appropriate. The economics of water heating, cooking and power generation are discussed in detail elsewhere [5]. It is important to note that for these end-uses, there are some renewable energy options which are comparable or even cheaper than some commercial energy options in an economic sense. Thus, solar water heating systems and solar cookers are economically viable when compared with electrical appliances. Use of biogas could be a cheaper option compared to LPG, kerosene, firewood or charcoal. The cost of electricity from small hydro, wind and biomass seems to be only marginally higher than that produced from thermal power plants and lesser than diesel electricity.

Solar ponds seem to be viable alternatives for production of low grade heat and potable water in coastal and brackish water areas. Similarly applications like space heating, cooling and drying can be economically viable for selected renewable energy sources in selected places. However, there do not seem to be economically feasible renewable energy options for irrigation pumping, transportation and industrial process heat at present. Examination of end-use wise economics also brings into sharp focus the need for sustained R&D and device development. Protagonists of sustainable development maintain that currently available technologies/devices for renewable energy utilization are adequate and that there is no further need for R&D or technology development. It can be argued that this is not true from a developing country perspective. There is a vast scope and, in fact, need, for developing innovative technologies suitable for local utilisation, for local production and with local talent for widespread renewable energy utilization.

5. Renewable Energy Options for Human Settlements

From the above sections, it is apparent that there are resource, space, technology and economic constraints for renewable energy utilisation in human settlements and that it is not pragmatic to push all renewables in an unqualified manner. It is also clear that all the renewable energy devices can not be used in all locations and for all types of settlements. Hence it will be appropriate to discuss the options for different types of settlements. For this purpose, settlements will be considered under the broad classification of rural, urban and isolated settlements.

Rural Settlements: Rural settlements in developing and developed countries differ in many ways, but can be characterized by low population density, lesser constraints on land availability and higher availability of biomass residues in comparison with urban settlements. Rural settlements in developing countries are further characterized by poor infrastructural facilities, lower degree of use of commercial energy and lower purchasing power. At the domestic level, use of expensive devices such solar water heaters, solar cookers, PV lanterns etc. can probably be ruled out in most of these settlements, but devices such as family biogas plants, improved biomass stoves and fuels like biomass briquettes can be acceptable, depending on family size, income level, social position etc. In Indian rural households, for example, economically well off farmers had been the main customers of biogas technology. Efforts to promote devices such as windmill water pumps, wood gasifier pumpsets etc. have largely been confined to demonstration activities. Improved stoves have met with a limited success and community biogas plants have largely failed. Also, use of biogas for water pumping has not been feasible at individual family level, largely because of the mismatch between water requirements and plant capacities. There are several reasons for failure of certain programmes carried out in rural areas since the last two decades, the major reason perhaps being the large difference between the perceptions of policy makers (who are also responsible for providing funds) and the actual requirements at grassroots level. Unfortunately a failure has a negative effect on policy makers instead of acting as a starting point or as a catalyst for formulating better programmes. In reality, there are several interesting possibilities of not only meeting the energy requirements but also to generate surplus in rural areas. The key issue is to increase the utilisation efficiency of biomass several folds by developing suitable devices/technologies and this is one of the important areas for technology development. Some theoretical case studies are outlined below, to give an idea of the possibilities that exist for sustainability.

Case 1: It is known that almost the entire rural population of about 480 million in India rely exclusively on biomass for cooking. The consumption figure is about 1.2 kg/person/day, which translates to 210 million tons per year for the entire country. This biomass is at present used very inefficiently to meet the cooking energy needs. One can consider the possibility of gasifying the biomass, (say at the village level) and supply the required producer gas through a pipeline network to all households for cooking. Firewood can be gasified directly, but other biomass residues may have to be briquetted and then gasified, the latter possibility having been demonstrated already [3]. 1.2 kg of biomass would yield about 3.0

Nm^3 of producer gas. The normative useful energy required for cooking and water heatin in 620 kcal/person/day, which can be provided by burning 1.13 Nm^3 of gas in a gas stov with 50% thermal efficiency, which is not too difficult to achieve. This would leave enoug gas to run a dual-fuel engine to generate 0.56 kWh of electricity. At the national scale, thi would translate to 98.3 billion kWh/yr, whereas the present rural consumption is only abou 43 billion kWh/yr. The above calculations are represented in Figure 5.1, which is sel explanatory.

The possibilities offered by the above mentioned route are clearly worth considering

Case 2: The community biogas plant programme, through conceptually sound, failed to tak off, perhaps due to lack community spirit or community level organisational structure. A alternative model based on commercial utilisation of dung could be thought of. A hypothetical case is shown in Figure 5.2. Instead of voluntary contribution of dung, a pric can be fixed on dung as well as on gas. At 5 paise per kg wet dung and at Rs.1.80/m^3 fo biogas, a family processing 2-3 cattle can sell 1500 kg/month of dung and earn Rs75/month. At a per capita requirement of 620 kcal (useful) per day a family of 5 would need about 1.4 m^3 per day, and would have to pay Rs.75 per month for gas. It can be noted that the prices are worked out so that there is no net monetary gain or loss to the family, taken at the aggregate level. A biogas company set-up in the village can process the dung in a high rate digester and produce biogas. After meeting the cooking requirements, an excess of 1.1 m per day per family is available for generation of electricity which can be sold to the local electricity board at the rate of Rs.1.75/kWh (current rate for Gujarat for electricity produced from renewable sources of energy). It can be seen from Figure 5.2 that if the company can process dung from 100 households, there can be a net income of Rs.5000 per month, which should be attractive for a rural entrepreneur. Higher gas production rate is possible if the exhaust gas from the dual-fuel generator, which is abundant, can be used to maintain the reaction at high temperatures. Clearly, the economics would be more attractive for large scale operations.

Case 3: Biomass residues like sugarcane leaves, mustard stalks, cotton stalks, lantana etc after a certain minimum amount of processing, can be pyrolysed to get carbon rich materi with yields upto 30%. This can be mixed with clay and extruded in a briquetting machine to produce charcoal like material which burns efficiently with no or little smoke and would be ideal for use in hotels etc. in nearby towns. With all the operations like chopping, briquetting etc. carried out with the help of a diesel genset, the diesel and labour cost component of the briquettes works out to about Rs.0.6/kg. If the diesel generator is coupled to a gasifier operating on briquettes (not necessarily charred), the processing cost will be much less. If biomass can be procured at Rs.0.5/kg, the cost of briquettes works out to about Rs.1.5/kg and these can probably be sold in the market for Rs.2/kg giving a profit margin of Rs.0.5/kg. With a plant capacity of 1 Ton/day, the monthly income could be Rs.15,000/-.

The above cases might seem unrealistic. It should be borne in mind that perhaps some such ventures might have already been attempted and met with failure. In most cases, the failure could be traced to deficiencies/inappropriateness of the technology employed, along with lack of applied R&D support, institutional support etc. What is emphasized here is that, once reliable and appropriate technologies/devices are developed, with necessary credit, marketing and applied R&D support, rural settlements can produce surplus energy in a sustainable manner.

Isolated Settlements

These are essentially the satellite townships, which grow as extensions of an existing city or around an industrial activity. These settlements are characterised by inhabitants with a relatively higher income with consequent high demands of LPG, electricity etc. Providing sanitation, drinking water and other facilities is usually a very expensive proposition. A detailed exercise has been carried out for TERI city, which is essentially an isolated settlement, for managing the colony with minimum dependence on conventional energy sources [4]. Some of the recommendations of this study were:

i) Use of solar cookers, solar water heaters and energy efficient passive building design for minimising the household energy consumption.

ii) A water hyacinth pond, both to treat the sewage generated by the settlement and to provide the feed material for generating biogas for meeting all the cooking energy requirements of the colony. It is estimated that to meet the cooking requirements of 400 inhabitants, an area of 1.5 hectares is needed for growing, harvesting and processing water hyacinth. This works out to 37.5 m^2/person.

iii) A larger pond for producing water hyacinth and converting to biogas, which can run dual-fuel engines with a capacity of 500 kW. The area requirement was about 12 ha.

iv) A PV system for pumping ground water needed for the entire campus.

The site of TERI campus is highly uneven, with several depressions which can serve as containments for water hyacinth ponds after suitable lining, embankment etc. Also, the land is not very productive and hence energy plantations may not yield enough biomass.

Different settlements might dictate different options, depending on the energy use intensity of the settlement, availability of renewable energy sources and geoclimatic conditions. It is neither feasible nor desirable to have "fixed" technological solutions for meeting the energy requirements of the isolated settlements in a sustainable manner.

Urban Settlements: Considering the high population densities and consequent restrictions on space availability and the high energy use intensities arising primarily out of transportation requirements, the use of renewable energy for urban settlements is limited. At the household level, solar water heaters and solar cookers are the only devices that can be used by relatively well off families. Providing energy, especially for cooking, for urban slums would be a very difficult task. Solid fuel briquettes, made from MSW, leaves and other waste can perhaps be made available for these areas. Relying on energy conservation is probably more feasible than use of renewable energy sources for urban settlements.

Sub-regional (National) settlements

At this level, planning and implementation would be much more complicated if a large share of renewables is desired in the overall national mix of energy sources. Use of localised resources like hydro and wind would be much more effective if a national power grid exists Management of sub-regional settlements in a sustainable way depends heavily on factors like political will, ability of the various government bodies and institutions to carry out bold and innovative programmes etc. The development and adoption of biogas technology, smal hydro, improved stoves etc. in China is the most illustrative example of what can be achieved at the national level.

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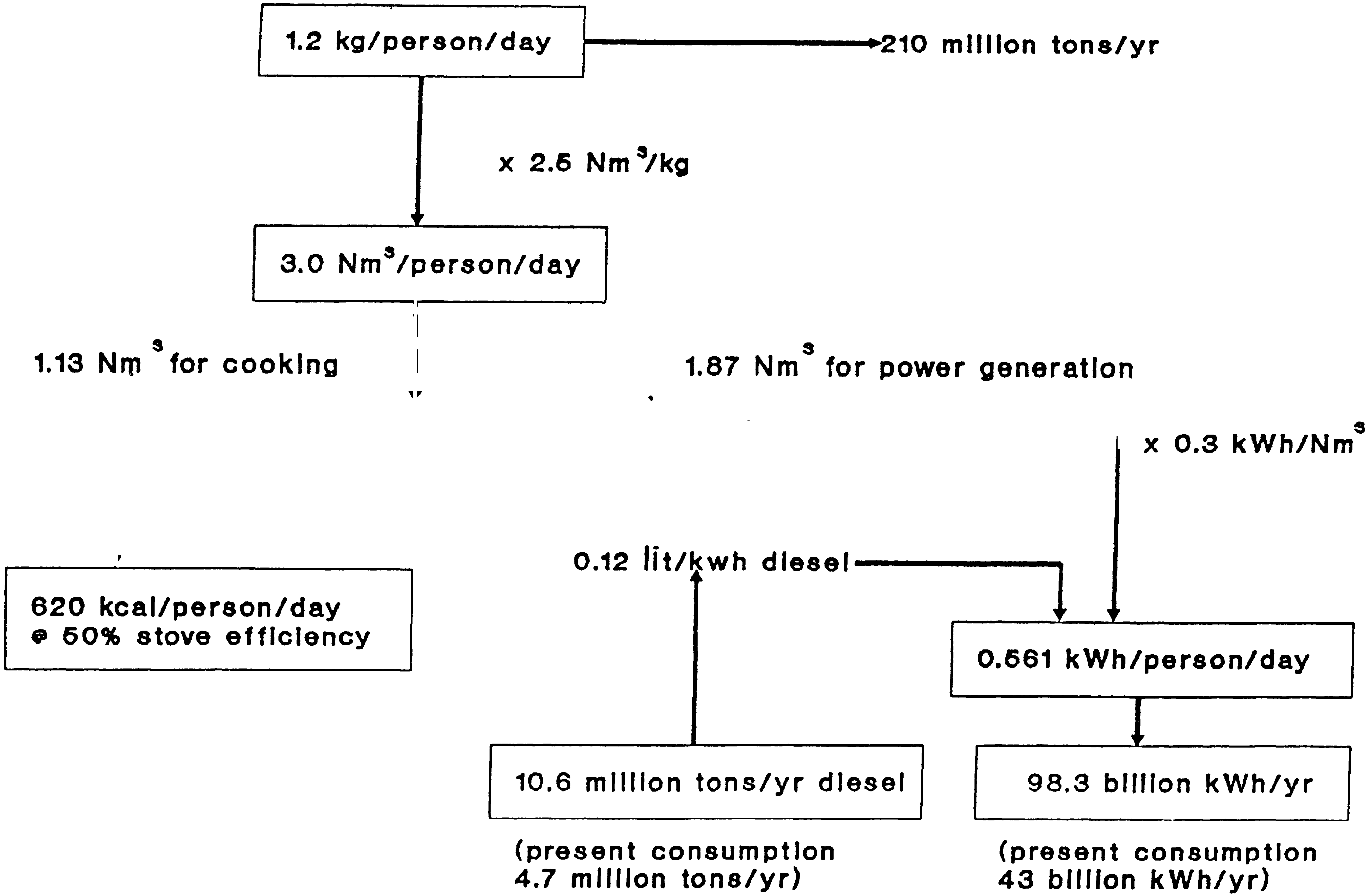

Figure 5.1: A hypothetical scheme for producing cooking gas and electricity from biomass

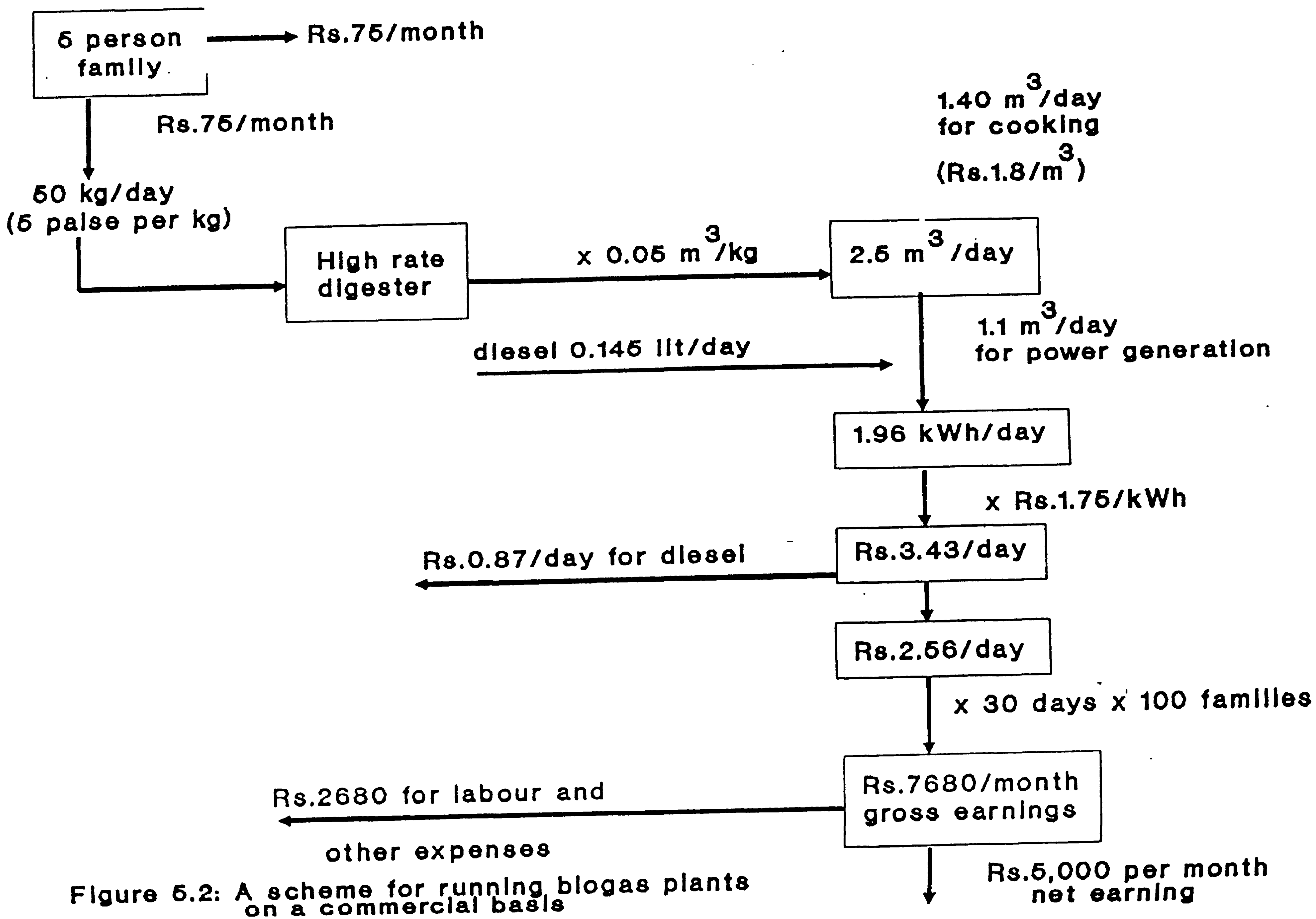

Figure 5.2: A scheme for running biogas plants on a commercial basis

ISSUES ON DEMAND SIDE MANAGEMENT IN POWER SECTOR

ENERGY SCENARIO IN INDIA

In a developing country like India where per capita consumption of energy is quite low (equivalent to 273 kg of oil equivalent (kgoe) in the year 1987 as against more than 4,500 kgoe in the OECD countries), the demand for energy is bound to grow to facilitate all round socio- economic development. The past trend in per capita energy consumption during the quarter of a century between 1952 and 1987 indicates a tendency towards more intensive overall use of electricity and commercial energy in the Indian economy

The per capita final energy consumption has increased from 224.4 kgoe in 1953 to 273.4 kgoe in 1987 at an implicit average annual growth rate of 0.6%. The share of commercial energy consumption rose from 26% in 1953 to 47.5% in 1987 at an average annual rate of 2.4%. In case of electricity, the per capita consumption growth has been very much higher and it grew from 21 Kwh to 203 Kwh i.e. @ 6.9% per annum.

GROWTH OF POWER SECTOR

India's power generation industry has grown rapidly. The installed power generation capacity has increased 53 times from 1362 MW in 1947 to over 72300 in 1993 and compares in size with the power generation industry of UK, Germany and France. Supply of electricity, however, continues to lag behind the demand for it.

Demand for electrical power in India which has increased by 8% annually over the last two decades would continue to grow rapidly in the future. It is estimated that during the 8th five year plan demand for electricity would grow about 10% annually as against expected growth of 5.5% in GDP. During the current year development plan, it is envisaged to augment generation capacity by 30500 MW. However, even with this order of capacity addition power at the end of the plan period vis-a-vis the demand for it would not be any better than at the beginning of the Plan when there was 8% overall electric energy shortage and a peak time deficit of about 20%. Cost of power generation is also increasing in terms of capital required as well as operating costs. Also increasingly expensive equipment for pollution control and environmental protection is being required to be installed in new power stations.

India had been adopting to growing demand for electricity by planning of new additional generation plants. The principal planning issue
was how to meet this demand at the lowest cost. This process could be called supply side planning. Essential feature of supply side planning is that choice lies between different generation plant options including configuration of steam turbine, whether combined cycle or combustion turbine and on the primary source whether oil, coal, nuclear, gas or hydro and unit size are typical of the issues that are addressed in this supply side planning.

On the other hand, developing countries have been resorting to demand side management measures to bring down level of energy consumption without affecting level of output in the consuming sector. DSM performs 2 main functions :

* reduce demand for electricity in the consumers' premises through improvement in efficiency where this is economical and/or

* reduce cost by transfer of energy consumption from times of high demand to times of low demand where this is economical.

It has long been recognized that influencing the pattern of consumer demand could bring considerable reduction in cost without adversely affecting the service to the customers. By reducing peak demand or shifting load from day to night or developing loads to fill valley, the reduction in capital and operating cost could be achieved. Activities designed to achieve such objectives are generally termed as **Load Management** which had been practiced by many electricity utilities since several decades. Most basic mechanism for managing load is tariff structures, i.e. time of use tariffs.

The term **Demand Side Management** (DSM) is synonymous with load management and has now replaced it in most contexts. It is the term widely used for any approach to influencing consumer load to achieve desirable objective.

DEMAND SIDE MANAGEMENT

Demand Side Management can be termed as a set of initiatives taken by utilities beyond customers meters to influencing consumer to either shift load to times of lower demand and/or strategic energy efficiency improvement in the customer premises.

Possible measures that fall within the meaning of DSM are :

* Tariff incentives

* Direct load control

* Promotion and marketing

* Transfer of load to other energy sources.

Direct load control is used to switch out certain loads during the time of high demand. In promotion and marketing, utilities can encourage use of more efficient appliances, leading to reduced energy wastage while still providing required level of service. Role of utility may simply to make information available on energy and cost saving practices and devices or it may offer various inducements to customers to promote these developments.

DSM measures are sometimes resorted to switch demand from electricity to other energy sources including renewables. Utilities can encourage these transfer by contributing to the technical development of non-electric or dual energy equipment and by implementing proper financial scheme to facilitate substitution.

COMPONENTS OF DEMAND SIDE MANAGEMENT

The electricity prices must correctly reflect the average generation, transmission and distribution costs of electricity incorporating fuel cost, overhead and investment cost. If this is not true then choice made by customers and by generators will not necessarily be consistent. If prices are higher than cost, then number of options to foster savings of electrical energy will appear to be deceptively profitable. If prices are lower than cost, this will have contradictory two fold impact; customers will have no spontaneous interest in saving electrical energy but it may be in generators interest to subsidise such saving in order to avoid operating losses.

Rate structures – the key to DSM

The major issue for electricity producers and distributors is to satisfy consumption demand for both energy and power. By their very nature electricity demand load curves have peaks and dips.. Consequently idea of average cost has only limited validity, as cost vary considerably between off-peak hours to peak hours. This is especially true for generation base in which peak or priority generation is handled by conventional thermal resources.

The above reasoning applies also to specific hourly and seasonal period. If prices reflect cost of these periods, a policy of incentives to save energy or replace some forms with other will be fully attractive for the period in which prices are high.

Consequently rate structure plays key role in implementing DSM. Systematic implementation of time of use tariff schemes had been very effective in progressively levelising daily load curves. Consumers are given appropriate information on the difference in electricity cost at different times, with a precision suited to their demand level; by this way consumers can make choices which infact have revealed to be effective in improving SEB's generation and distribution costs. In some ~~countries~~ electricity supply companies have increased available range of tariff options with the aim of providing customer with an almost-on-real-time information on the electricity production cost.

Concluding tariff aspect the following two basic fundamentals are relevant :

* By sending the right cost signal to customers at the right moment, customers can take steps themselves to use energy rationally.

* By ranking costs according to different use period, generators, their regulatory agencies or national energy policy makers can determine why and where it is profitable to take other measures in to order to save electrical energy.

Appropriate steps for DSM :

- R&D, industrial policy, communication and information.

Once the criteria determining steps to be taken for DSM are clear, all appropriate measures for meeting these criteria may be justified, no matter whether they involve generators, distributors or public authorities. Generators and distributors seems to be neutral in this type of action, as long as its rates allow them to recover their cost including hourly and seasonal variation. But in fact it is in the generators, distributors interest to improve electricity products which must compete with products using another type of energy. This explains the need for R&D on the existing/future products together with industrial policy in cooperation with equipment manufacturers.

On the so called captive market, regulatory agencies role is to encourage generators and distributors to reduce their price and therefore their costs. They must also be encouraged to link rate structure with the product, in order to smooth out the load curve where this is necessary.

DSM is especially advantageous when the cost to the electricity system, whether overall or for specific periods, are high. This is when electrical energy savings or the substitution of other energy forms, such as in-house generation/co-generation becomes economically viable. Consequently, the key tools for DSM is the rate structure, provided it transfers costs correctly to the consumers. Such structures show consumers usefulness of achieving savings or adopting other forms of energy and they help public authorities to identify potential energy saving. Then, working either alone or in cooperation with other actors generators and distributors can provide consumers with information on the rate system and are therefore involved in active DSM, although it remains to be seen just how effective the approach is in relation to its potential.

Adding today or in the near future restrictions related to the environment does not alter the basic problems which needs to be dealt with in global terms, by adopting a multi-energies approach. An effective DSM could lead to substitute electricity for other more polluting fuels, particularly when electricity is generated by hydro and/or nuclear sources.

In addition to systematic consideration of demand side as well as supply options, increasing emphasis is on environmental matters. Environmental consequences of electricity planning decision have in some cases to be regarded as externalities in the economic sense i.e. it is generally not possible to quantify them as cost or benefit to the utilities making the decision but rather they have a less easily measured effect on society as a whole. Resulting approach is ~~commonly~~ called **Least Cost Planning** (LCP). Distinctive features of LCP are :

- Evaluation of demand side as well supply side options on comparable basis.

- inclusion of environmental externalities in the evaluation.

Essential new element in least cost planning is that more consideration are now examined in the analysis; demand side as well as supply side solutions are assessed and environmental consequences are evaluated.

Possibly because of this potentially misleading impression a further term, **Integrated Resource Planning (IRP)** is often used to describe essentially the same approach. This is more descriptive term and conveys better the important aspects of the process.

The key players for implementing a well conceived DSM programme include apart from utilities, distribution companies, end users, energy efficient equipment manufacturers, consultants, energy service companies and the regulatory agency.

Integrated Resource Planning (IRP)

As a developing country India clearly faces a major financial, environmental and institutional impediments to meeting growing energy service needs of its citizens. These services can be provided by implementing end use energy efficiency, thereby allowing energy supplies to provide more energy services. While most developing countries will need to expand their energy supply in the future to meet their energy service needs, an approach of integrated least cost planning, offers treating energy supply and energy efficiency improvement options on equal footings and select least cost options first. This method also allows for environmental cost to be integrated in projecting cost of each option. This approach orients energy planners where from traditional focus on simply supplying energy and providing energy service by taking comprehensive method for providing energy service. Integrated least cost approach may defer or even eliminate new, expensive energy supply facility and can reduce reliance on fuel imports.

Major organizations working in DSM in the country include utilities such as GEB, MSEB, consultancy organization like Indira Gandhi Institute of Developmental Research (IGIDR), Tata Energy Research Institute (TERI) and Energy Service companies. Major energy efficient equipment manufacturers are also expected to take active role in implementation of DSM programme. EMC is contemplating to conceive and implement DSM programme for GEB in cooperation with TERI and other allies.

Energy Management Centre is interested in ideas and allies both from the utilities and all local agencies and energy efficient equipment manufacturers in introducing the concept of DSM to meet the growing demand on the least cost.

Training Programme for I.A.S
Officers on Energy & Development
of TERI, New Delhi

Energy Use and Economic Growth in Developing Countries

By

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India has a mixed economy and most of industries in the core sector like power, steel, railway, civil aviation, coal, petroleum etc. are state-owned. However, as India is the largest democratic country in the world, the aspect of its industrial structure and ownership is debated quite freely and frequently and reviewed from time to time. If necessary, some of the industries in core sector too are open for private investment. For example, Tata Iron and Steel Company (TISCO) is fully private owned; Oil India Limited (OIL), a full-fledged hydrocarbon exploring and producing company, has been, till recently, a joint sector company. A number of private companies are operating in civil aviation industry also. Some of the coal and iron mines are also operated by private sectors.

India, being a developing country, has witnessed a rapidly growing energy needs owing to fast industrialisation and increasing demographic profile. About 60 % of its total energy requirement is contributed by commercial energy (oil, coal, gas, hydro and nuclear electricity) and the rest by non-commercial energy. The requirement of commercial energy over the past two decades has increased at an average annual rate of 5.4 % whereas the GDP has grown at the rate of 4.3 % only (Fig.1).

India, in spite of having huge energy resources, has been following a energy policy that limit the use of petroleum in the sectors where its substitution by other resources like coal etc. is either not possible or highly uneconomical. Nevertheless, petroleum has been the most preferable source of energy because of lower degree of losses and higher energy conversion factor as compared to most of the other commercial energy sources.

Until 1970, planning of GDP growth and energy availability had been relatively easier. However, oil shocks in 1973 and 1979-80 led to formulate and adopt strategies world over that could slowly reduce the dependence on oil. For instance, France opted for a comprehensive programme for use of nuclear energy; USA looked towards coal; USSR drew a long-term plan to use its natural gas resources internally as well as export to Western European markets. Additionally, conservation and efficient use of energy, switchover from more energy intensive industries to less energy intensive ones and delocalisation of industries from developed countries to developing countries are some of the fallout measures adopted over the world to meet the energy demand.

India's concern about its energy reqyirement and self-sufficiency dates long back to the energy crises. Its endeavour has been to meet its energy needs by (i) increasing indigenous production capacity and (ii) conservation and efficient use of energy. The outcome, so far, are, however, not of desired level. The following sections attempt at analysing the above aspects vis-a-vis the situation in developed countries and explore the areas wherein further improvements could be possible.

India's future requirement of energy, particularly of petroleum, up to 2010 AD has also been estimated under different variants. The magnitude of petroleum import is assessed for each variant for long-term energy planning.

Energy-GDP Relationship:

Yearly and percent growth over previous year of energy and GDP are shown in Fig 1,2 and 3 respectively. It is observed that the GDP, between 1971-88, has increased at an average annual rate of 4.3 % whereas the commercial energy requirement has gone up at the rate of 5.4 % a year. Analysis of the data during oil shock periods reveals the following impacts,

- In 1974, there was practically no rise in GDP whereas energy needs went up by 4 % (may be statistics problem)
- In 1979, GDP growth as compared to the preceding year was negative (-5 %) whereas energy requirement rose by 5.5 % (may be statistics problem)

In 1980, GDP increased by 6.5 % eventhough energy requirement was of the same magnitude as that of the previous year. This could be possible due to the deliberate measures taken for conservation and efficient use of energy.

A plot of Ln energy vs Ln GDP is shown in Fig 4. It is observed that the data points are quite linear with slite scattering during the oil shock periods. Assuming a relationship as,

$$En = a * GDP^{\alpha} \qquad ..... (1)$$

regression analyses have been carried out considering three data ranges viz. 1971-88 (Fig 4); 1971-79 and 1980-88 (Fig 5) and the values of the constant 'a' and the elasticity of energy-GDP (α) are as follows,

Data- Period	**Value of "a"**	**Value of "α"**	**Correlation Coefficient "R^2"**
1970-88	291.65	1.1819	0.989
1970-79	287.82	1.1844	0.921
1980-88	419.86	1.06	0.986

It is observed that the percent growth in energy requirement for 1 % growth in GDP declined from 1.1844 during pre-'79 period to 1.06 during post-'79 period, thereby, an improvement in energy use by about 11 %. In the above regression analyses total GDP but only commercial energy were taken with the assumption that in total energy, the percentage of non-commercial one is constant and the contribution in total GDP is proportionate throughout. If it is not, the regression has to be split-up into two parts assuming,

$$En_c = a_c * GDP_c^{\alpha} \qquad .... (2)$$

$$En_{nc} = a_{nc} * GDP_{nc}^{\alpha} \qquad .... (3)$$

where, the suffixes "c" and "nc" stand for commercial and non-commercial types of energy and GDP. If energy-GDP elasticity is equal for both commercial and non-commercial types, combining eq.(2) and (3) yields,

$$Ln\ E_t = Ln\ a_t + \alpha_t * Ln\ GDP_t \qquad .... (4)$$

where,

$$E_t = En_c * En_{nc}$$

$$GDP_t = GDP_c * GDP_{nc}$$

$$a_t = a_c * a_{nc}$$

In case of India, the first part of the assumption is almost true but GDP data corresponding to commercial and non-commercial types of energy are not available separately. In case of developed countries, the above assumption may not, strictly, be true but the contribution of non-commercial energy is too low to influence significantly.

Energy Losses:

The loss of energy occur mainly in two ways-(i) transportation from one area to another and (ii) transformation of energy from one form into another. Yearly loss of energy for India as well as, for comparison, other countries / continents are displayed in Fig 6 and 7 . It can be seen that the total energy loss in India till 1980 had been, on average, about 6.5 % which was less than that of Europe (6.7 %), USA (11 %), Asia (7 %) and world (7 6 %). However, the countries/ continents mentioned above improved a lot after 1980 but, on contrary, the loss scenario in India worsened and by 1987, the loss percentage touched a level of 12.6 which is far above the world average of 7.8 %, Europe 6.1% and even the Asia average of 9 %.

A micro analysis reveals that a major portion of the energy loss has been in the electrical sector alone (Fig 7). After 1986, the loss of electrical energy in India has been, on average, as high as 44 % as compared to the world average of 14 %, Asia average of 21.5 %, USA 16 %, Japan 11 %, Europe 11.5 %, Canada 5.7 % and Australia+ New Zealand 23 %. The possible reasons could be the logistics, the geographical situation, technological obsolescence and pilferage. These aspects need immediate attention and remedial measures to be taken to match at least with Asia and possibly with developed countries.

The advantage of having big power plants is that it can directly generate high voltage required for long distance transportation. In this case, the loss of energy is in two ways- (i) long distance transportation and (ii) transformation from high voltage into low voltage before use. In case of smaller plants, transportation loss is lesser because of short distance transportation but the transformation needs to be done twice viz. (i) from low voltage into high voltage before transportation and (ii) from high voltage into low voltage before use. Additionally, construction of a number of smaller power plants .may, combined together, require more capital and infra-structure investments. Thus, a relative economic analysis alongwith other considerations like regional resource availability, socio-economic development etc. would lead to an optimum capacity of a power plant.

Efficient Use Of Energy:

The oil shocks in 1973 and 1979-80 led to global awareness for adopting measures to maximise economic development with minimum energy consumption. The usual yardsticks to measure the efficiency are,

(a) Energy Intensity:

Energy intensity, the amount of energy required to produce a given unit of economic output, is influenced by several factors like availability of energy resources and their relative price structure, pattern of energy use, industial structure, geographic and climatic conditions etc. Variation in energy intensity for different countries/ continents are shown in Fig 8 and 9. It is observed that the net energy exporting countries have not paid much attention to reduce energy intensity, whereas energy importing countries are continuously trying to improve by energy conservation, its efficient use and major restructuring of economics. However, the magnitude of improvement in energy intensity in developed countries has been higher than for developing countries. For instance, Japan has improved its energy intensity by 33.5 % during 1973-1988; USA by 21.7 % during 1976-1986 and Europe by 19.1 % during 1973-88. In case of India, the energy intensity figure has been quite fluctuating and, in general, it has an upward trend (increase by 19.3 % during 1970-1987). Further, it is seen that for the same amount of GDP, the amount of energy requirement in India is 2.8 times of world average; 4.6 times of Japan; 2.3 times of USA; 2.7 times of Europe and 1.28 times of average for Asia.

Thus, there is much scope for reducing the India's energy requirement by about 15-20 % just by improving the energy intensity at least to the level of Asia average. This would be possible through continuous efforts for conservation, improvement in efficiency, restructuring and delocalisation of industries, more competetive environment etc.

(b) Energy-GDP Elasticity:

This is the percent growth in energy requirement for one percent growth in GDP. The lower the value of elasticity the higher is the overall efficiency. However, the industrial structure of a country has significant inflence on the elasticity. In case of energy intensive industries, efficiency can be quite good eventhough the value of elasticity is relatively high. Variation in elasticity with time for different countries / continents are displayed in Fig 10 and 11. For most of the developing countries, where the non-commercial energy is being replaced by commercial one, the value of elasticity is higher than that for developed countries. The analysis of the data for the period 1970-88 indicates that for developed countries the value of elasticity ranges between 0.8 and 1.0 whereas for India it is around 1.2. Thus, there is scope for improvement in efficiency of energy use by 20 -25 % .

However, energy consumption per capita in India is far below the level of developed countries and the world average. In this aspect, the developed countries have enough cushion to curtail their energy requirement.

Self Sufficiency:

Self-sufficiency in commercial energy requirement of different countries / continents are displayed in Fig 12 and 13. The level of self-sufficiency can be increased basically by;

(i) enhancing the level of energy production from indigenous sources and (or)

(ii) containing the energy requirement by conservation and efficiency improvement, delocalisation of energy intensive industries etc.

However, the process of substitution of non-commercial energy by commercial one may have both-positive or negative impacts on self-sufficiency. For countries having limited indigenous commercial energy resources like Japan , import is perhaps the only option which would further reduce its self-sufficiency level. This forced reduction may, to some extent, be negated by ways (ii) as Japan has demonstrated. On the other side of the scale, USA has increased its indigenous production to meet the energy demand and, as a result, its sufficiency level in commercial energy has gone up from 67 % in 1967 to about 80 %. Europe improved the sufficiency level from around 35 % during early seventies to about 60 % in 1988. India's self-sufficiency till 1974, had been around 75 % but after start of hydrocarbon production from Western offshore, the level gradually increased to about 90 %.

The net energy exporting countries (Fig 12) did not pay much attention to the above measures and, consequently, self-sufficiency level declined from 380 % to about 215 % in Africa; 170 % to 130 % in Latin America; 1850 % to 400 % in Middle East.

Attaining a high level of self-sufficiency could be a goal as long as it motivates for increase in indigenous production and improvement in efficiency. However, it should not be a goal to be achieved anyhow and particularly at the cost of economic growth. May be, more investment is required initially for import of energy necessary for achieving the target of economic growth but it would have greater contributions in long-range.

Role Of Petroleum Sector In Commercial Energy Requirement:

Fossil fuels (oil, natural gas and coal) constitute about 90 % of the world's total energy requirement. Of which, oil alone accounts for around 37 %. The major energy consuming sectors are transport, industry, domestic and electricity generation. As oil is the most convenient commercial energy source, any change in its consumption pattern, reflects in corresponding variation in total energy demand.

The contribution of commercial energy in India has increased from about 40 % in 1960 to over 65 % at present. Of the total commercial energy, petroleum sector's contribution has been ranging between 30-37 %. Yearly contribution and self dependency in petroleum are shown in Fig 14 and 15. It is observed that till 1980, India's self-sufficiency in petroleum has been fluctuating between 30-40 %. However, the phenomenal growth in crude production from Western offshore fields helped in achieving a sufficiency level of 70 % during 1984-86. After 1986, slight decline trend is noticed due to outpacing demand growth.

A perspective plan is being drawn and mulyi-prong efforts are being made to meet India's future petroleum requirements.The major emphasis would be on,

- demand management ie. conservation, improvement in efficiency etc.
- increase in production through a optimum mix of intensive and extensive exploration, improvement in recovery factor by application of better and efficient technology etc.
- reduction in dependency on oil by restructuring of industries, substitution by gas, development of alternative sources of energy etc.
- expansion of its exploration and production activities beyond the national boundary

This would also help arrest the increase in import component.

(a) Inter-Fuel Substitution:

Recent crisis in Gulf has brought the subject of dependence on oil to the forefront again. Natural gas is well-positioned to make a significant immediate contribution towards lessening the dependence on oil and even greater contributions long-term. Gas can be used in various sectors like power generation, industries (fertiliser, petrochemical etc.), transport, domestic etc.

The usual criteria to identify the sectors for use of gas could be economic, energy conversion factors, socio-political or regional environment. Relative economic and ultimate profit could be the sole criterion for a indvidual or a private company but from national point of view latter ones may be equally important.

In India, in spite of a lot of planning and incentives, only about 60 % of the total gas production is used for various energy and non-energy purposes and the balance is either flared or reinjected. Recently, the aspect of gas utilisation has received more emphasis and the schemes are at various stages of implementation to reduce flaring of gas to a minimum level. The main bottlenecks in the process are :

* Huge initial investment in transportation and distribution systems
* Storage
* Formulation of uniform and consistent pricing policy.

Nevertheless, India has drawn a long-term plan for utilisation of gas and necessary infra-structure (national and regional gas grids etc.) would be generated in phases. This would help reduce the magnitude of oil import in future. In terms of economic and energy values, the priority sectors would be power, industry, fertilisers, petrochemicals and domestic and depending upon the availability of various energy resources and requirement an optimum mix can be evolved.

In addition to the above, the absence of an organised spot market also tends to restrict the international trade of gas. An international agency with the primary mission to promote the trade and use of natural gas may accelerate the process.

Future Energy Requirement:

Using the above energy-GDP model, an assesment of future commercial energy requirement of India up to 2010 AD has been made assuming (i) past trend of GDP growth, (ii) GDP growth at 4 % and (iii) GDP growth at 5 %. Further, two variants have been considered viz. (a) percentage of commercial energy in total would remain practically constant throughout and (b) contribution of commercial energy would grow gradually to 80 % by 2010 AD. The projections have been made under the premises that,

- there would be no oil shock in future,
- there would be no major revolution in energy related technology,
- efforts like energy conservation, efficiency improvement etc. will continue.

Future GDP growth and energy requirements under different variants are shown in Fig 16..21. The results are summarised below,

GNP Growth Rate	Variant	Energy Growth Rate
Past trend	(a)	3.23
	(b)	4.58
4 %	(a)	4.27
	(b)	5.64
5 %	(a)	5.33
	(b)	6.71
4 % up to 2000 and	(a)	3.80
stablising at 2.5 % by 2010	(b)	5.20

(a) Petroleum Requirement:

Assuming that the contribution of petroleum sector in total commercial energy would remain same, its requirement has been assessed under variants (a) and (b) mentioned above (Fig. 22..25). It is observed that the petroleum requirement in future would grow at the rate of 4.3 % and 5.3 % per year respectively for 4 % and 5 % future growth rates in GDP. Considering 98 % and 90 % of produced oil and gas respectively to be utilised for economic development, the net magnitude of import of petroleum under variants (a) and (b) is displayed in Fig. 26 and 27. As long-term production profile of OIL is not available, the same has not been taken into account to estimate the net import of petroleum.

Also, a third case considering GDP to grow at an average rate of 4 % per annum till 2000 AD and, thereafter, gradual convergence to 2.5 % by 2010, has been studied and the GDP growth, commercial energy requirement, petroleum requirement and the quantum of import of petroleum are shown in Fig. 28..31. It is clear that to enhance the level of self-sufficiency in petroleum, more thrust need to be on (i) rapid conversion of hydrocarbon resources into geological reserves, (ii) optimisation of production from established reserves and (iii) maximum utilisation of gas wherever possible.

Energy Pricing:

Price of any energy source is of two types viz. (i) international trading price and (ii) end-use price. Further, (i) has two components- the market price and the transportation cost. The former component is practically the same for all importing countries whereas the latter varies from country to country depending upon its geographical location, mode of transport etc.

The contribution of commercial energy in India has increased from about 40 % in 1960 to over 65 % at present. Of the total commercial energy, petroleum sector's contribution has been ranging between 30-37 %. Yearly contribution and self dependency in petroleum are shown in Fig 14 and 15. It is observed that till 1980, India's self-sufficiency in petroleum has been fluctuating between 30-40 %. However, the phenomenal growth in crude production from Western offshore fields helped in achieving a sufficiency level of 70 % during 1984-86. After 1986, slight decline trend is noticed due to outpacing demand growth.

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The international market price has witnessed a wide variation over the last two decades. It is heavily influenced by the geo-political environment and market factors ie. production and demand situation. For instance, coal prices in international market depends, to a great extent, upon the level of coal production in USA whereas the crude oil prices is dictated by production by Gulf- countries. It is observed that when the oil exporting countries production level is around 80 % of its capacity, the production-demand equilibrium is balanced. Any considerable increase in production may have a tendency to bring the price down if there is no corresponding increase in demand. The importing countries have hardly any control over the international market price. However, if deliberate measures are taken by these countries for conservation and efficiency improvement etc. the rate of groth in demand can, to some extent, be retarted.

The natural gas, so far, has not been a major energy source for international trading probably due to storage and long-distance transportation difficulties as well as seasonal variation in use-pattern. Additionally, gas has to compete with other energy sources (mostly with oil) within a country. In USA, a major portion of the total gas consumption is used for space heating and, therefore, the gas prices shoot up to more than double during winter. After the second oil shock in 1979-80, USSR had a comprehensive plan to export gas to western Europe. It is believed that with development of suitable storage and transportation technologies, natural gas would have fairly good potential for intercontinental trading.

The end-use prices of various sources of energy widely varies from country to country depending upon availability, industrial structure, economic and energy policies, taxation policy etc. For instance, countrywise variation in gasoline prices during third quarter of 1990 is shown in Fig 32. It is observed that of the total price, the tax component varies from 25 % in USA to as high as 76 % in Italy.

CONCLUSIONS:

- The growth rate of energy requirement for developing countries like India has been and would be higher than that for developed countries. In India, the commercial energy demand would grow at the rate of 5 - 7 % . The efforts should, therfore, be to (i) maximise the indigenous production and (ii) conserve and improve the energy efficiency.
- The loss of energy in India (particularly in electrical sector) is alarmingly high. The main reasons are obsolescence of technology, geographic and climatic conditions, maintenance of equipments, pilferage etc. These aspects need immediate attention and remedial measures may help reduce the electrical energy requirement by about 20 %. The loss of electricity can, to some extent, be reduced by having an optimum mix of big and small power plants distributed over the area. A decentralised system open for private investment in power sector may increase the competetiveness and, to some extent, reduce the chances of pilferage.
- So far economic output is concerned, commercial energy is more cnvenient and efficient than most of the non-commercial ones. However,the efforts of the developing countries like India should be to develop and utilise their indigenous unconventional energy resources like solar, wind, tide, bio-, geothermal etc.
- Per capita energy consumption in developed countries like USA is far more than in developing and undeveloped countries. Thus, the developed countries have good scope to curtail their energy requirement by further improvement in energy efficiency (at least close to Japan). A consertaive approach can also help in meeting the global energy requirement and ensure longer life of oil industry.

- India's self-sufficiency in petroleum has declined from 70 % in 1986 to about 60 % probably due to (i) higher demand growth rate than increase in production (ii) inadequate utilisation of gas reserves. Keeping this in view, a long term perspective plan has been drawn giving adequate emphasis on intensive exploration in established basins and extensive exploration in relatively unexplored basin.

- Oil is a swing product for India as well as for other countries particularly net oil importing ones. Thus, any change in total energy demand has greater impacts on oil demand. This could, to some extent, be overcome by consistent efforts to lessen the level of dependency on oil.
- Natural gas has a lot of potential to be used as fuel / feed stock in industries, transport, power generation, fertiliser, domestic etc. So far, utilisation of gas in India is only about 60 % of its gross production.Major part of its established free gas reserves is yet to be developed. Also, about 30-40 % of the hydrocarbon resources likely to be converted into reserves during the next 25 years is expected to be gas. Thus, it is imperative to expedite the actions for maximum utilisation of gas reserves and minimise its flaring.
- Economic valuewise, power generation and fertiliser could be the best options for use of natural gas. However, depending upon the need and the availability of various types of energy resources, an optimum mix can be evolved.
- Energy price, specially of oil, in different parts of the world is at variance because of several factors like geographical location of a country, basic production cost, taxation policy etc. The net importing countries and particularly the developing ones are most severely affected by any increase in price.

INDIA

Energy And GDP Growth

Fig. 1

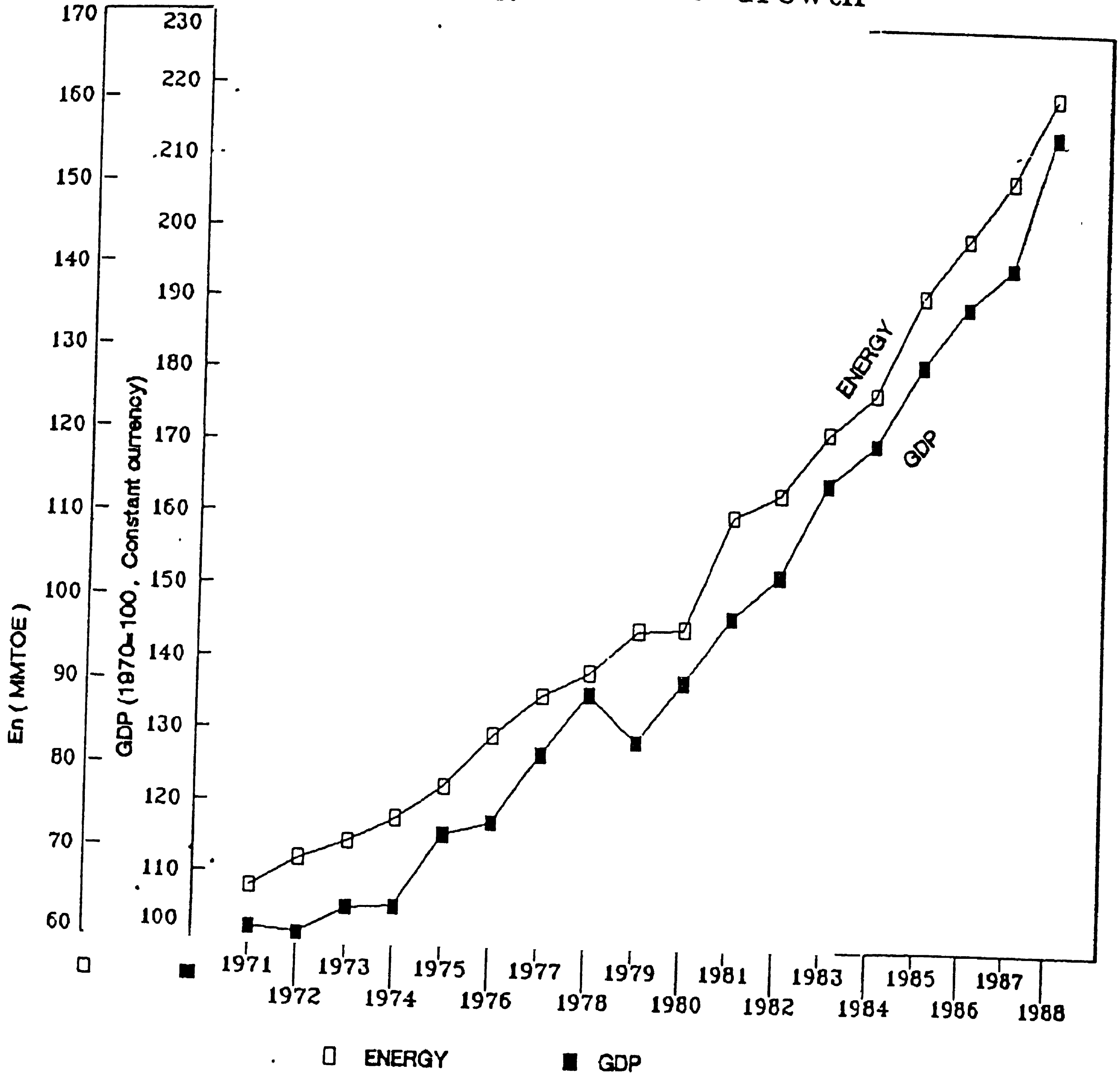


Fig. 2

INDIA

ENERGY AND GDP GROWTH

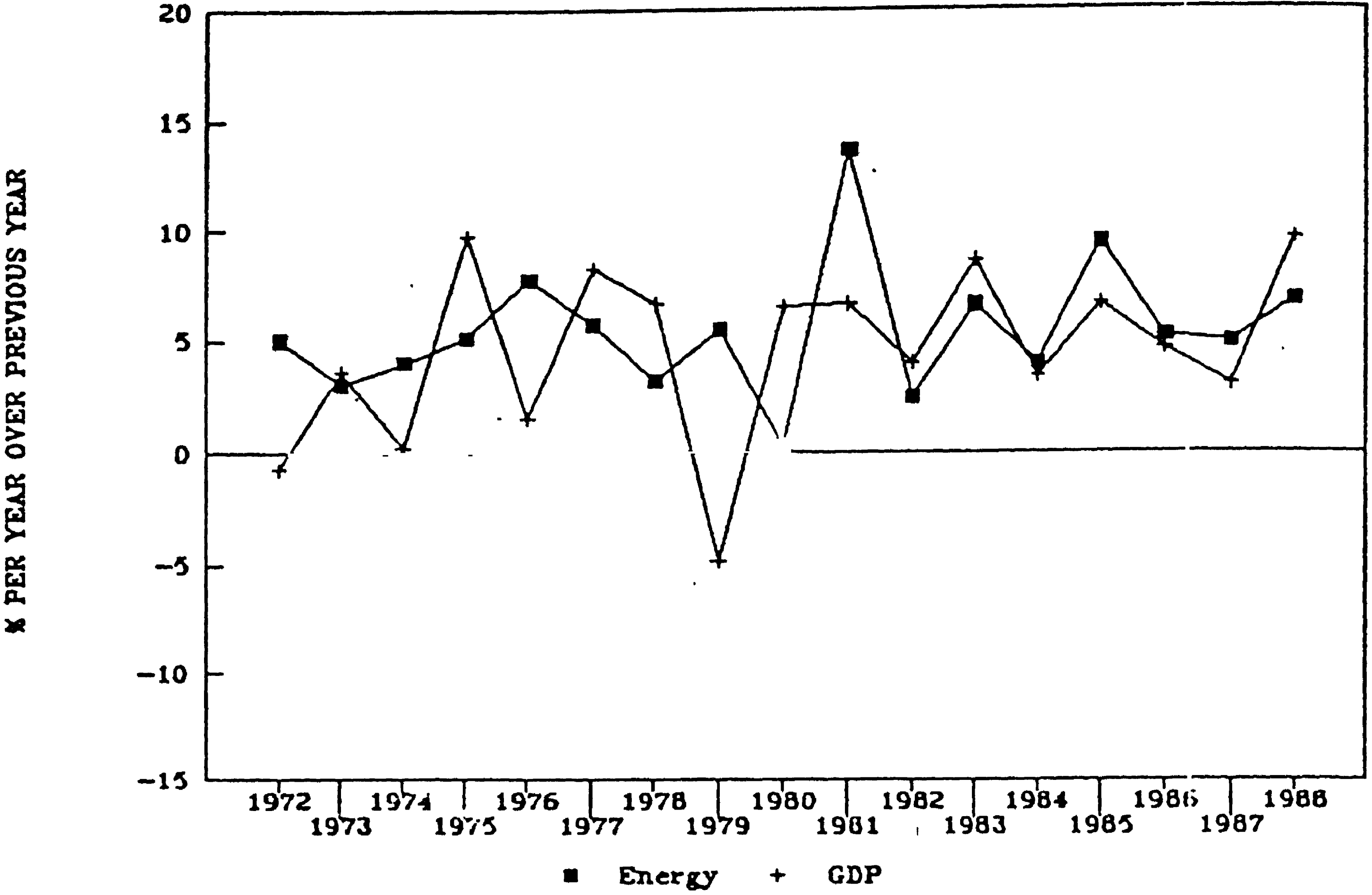
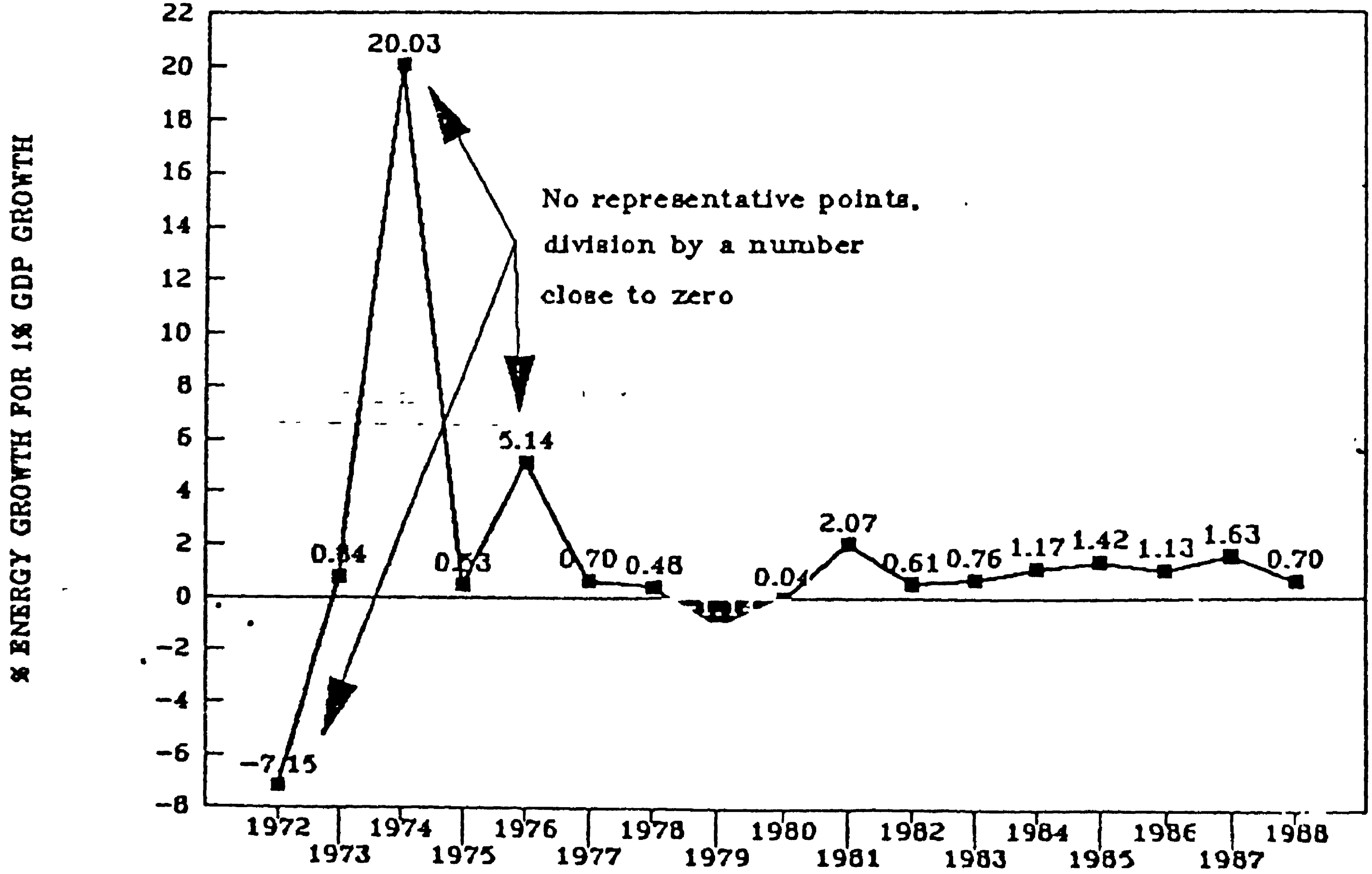


Fig. 3

INDIA

ENERGY AND GDP GROWTH



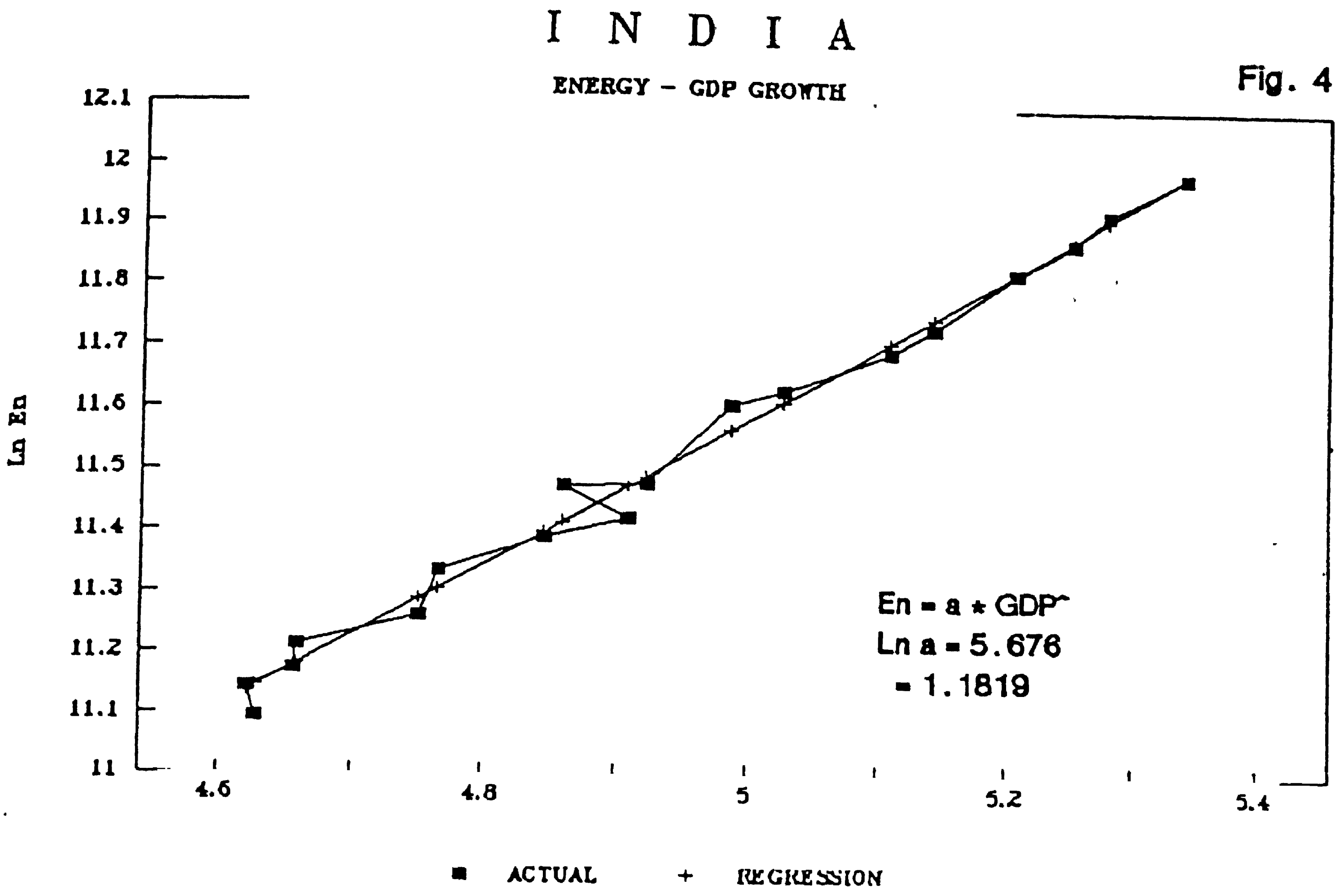
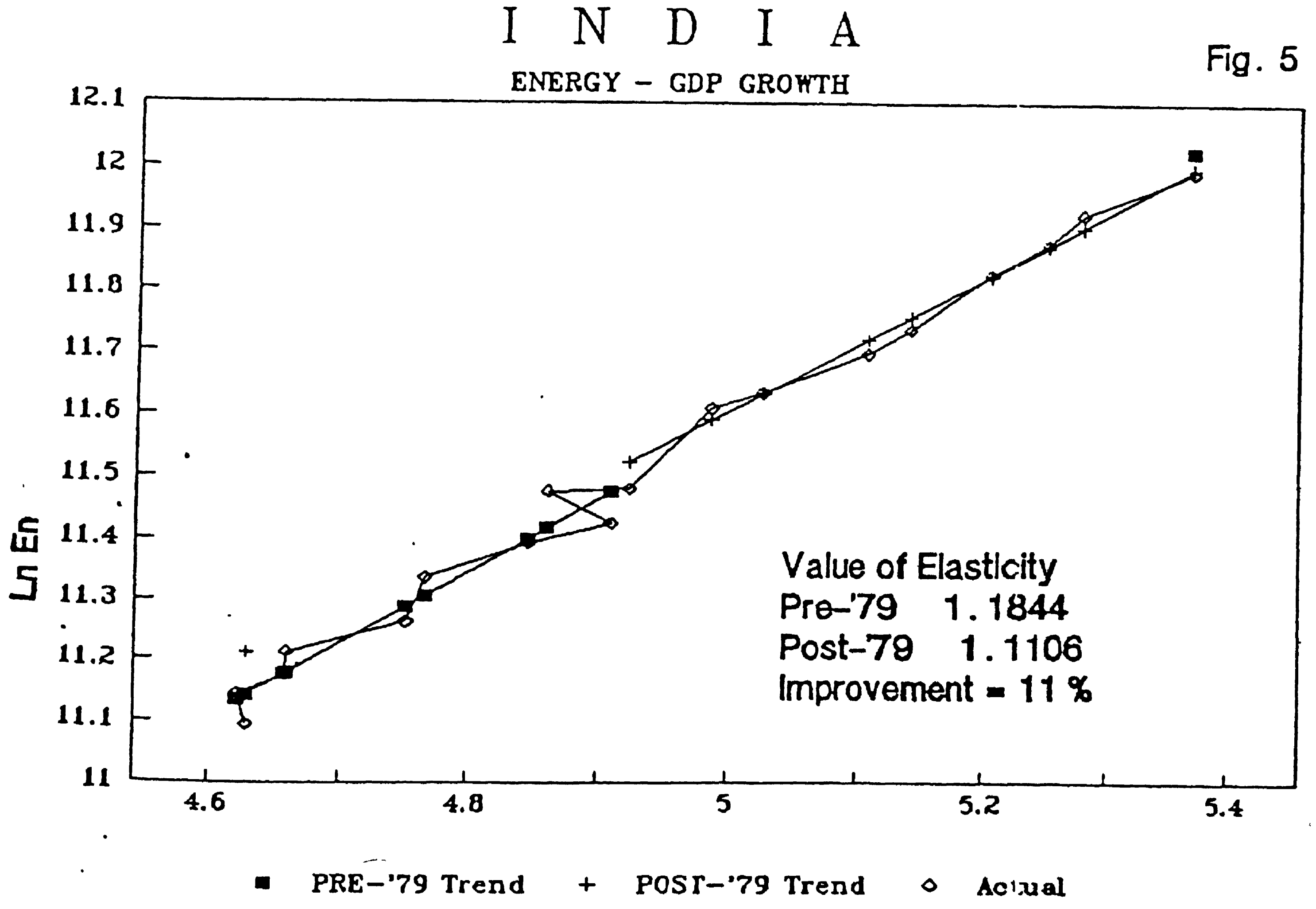


Fig. 4

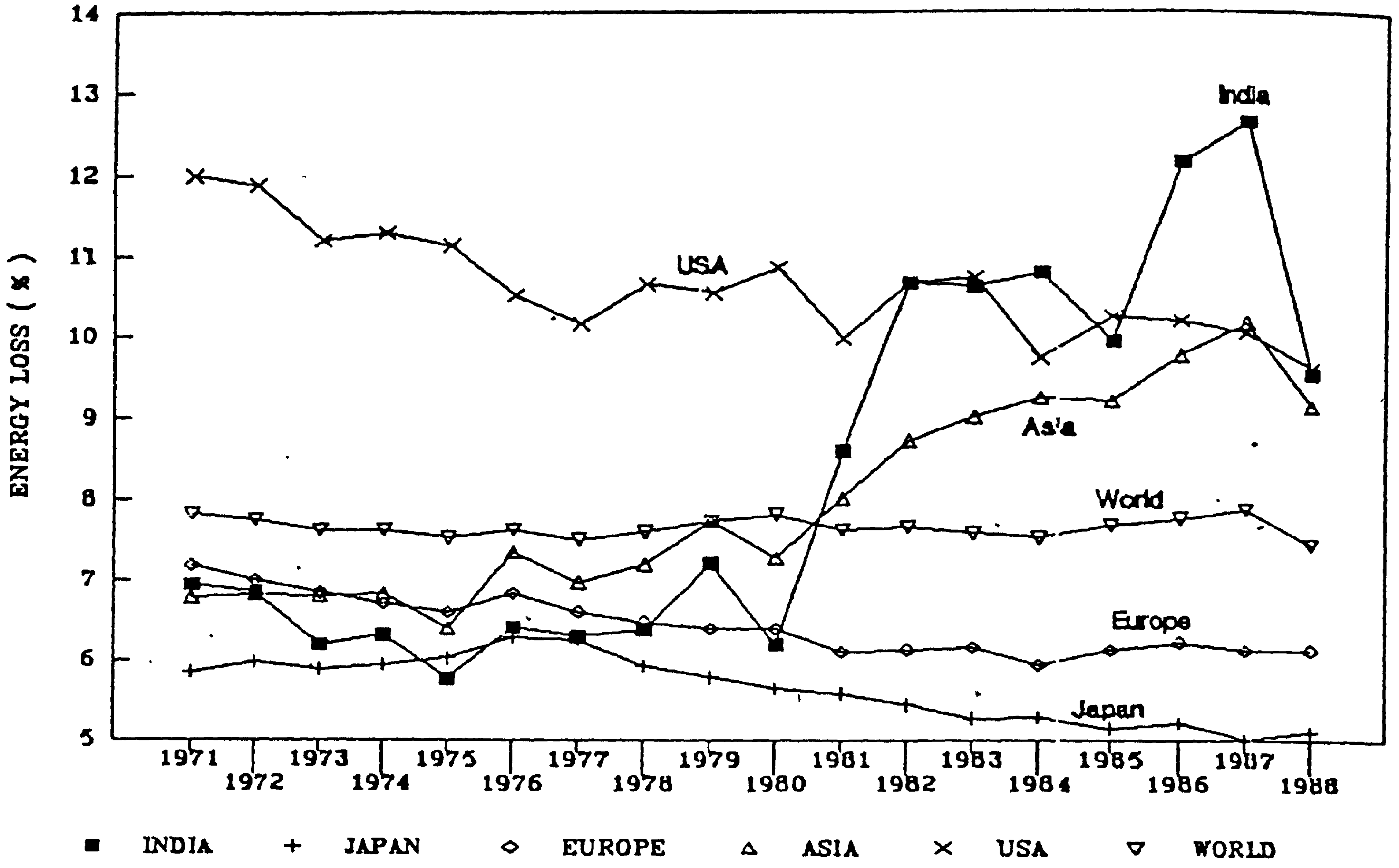


Value of Elasticity
Pre-'79 1.1844
Post-79 1.1106
Improvement = 11 %

Fig. 5

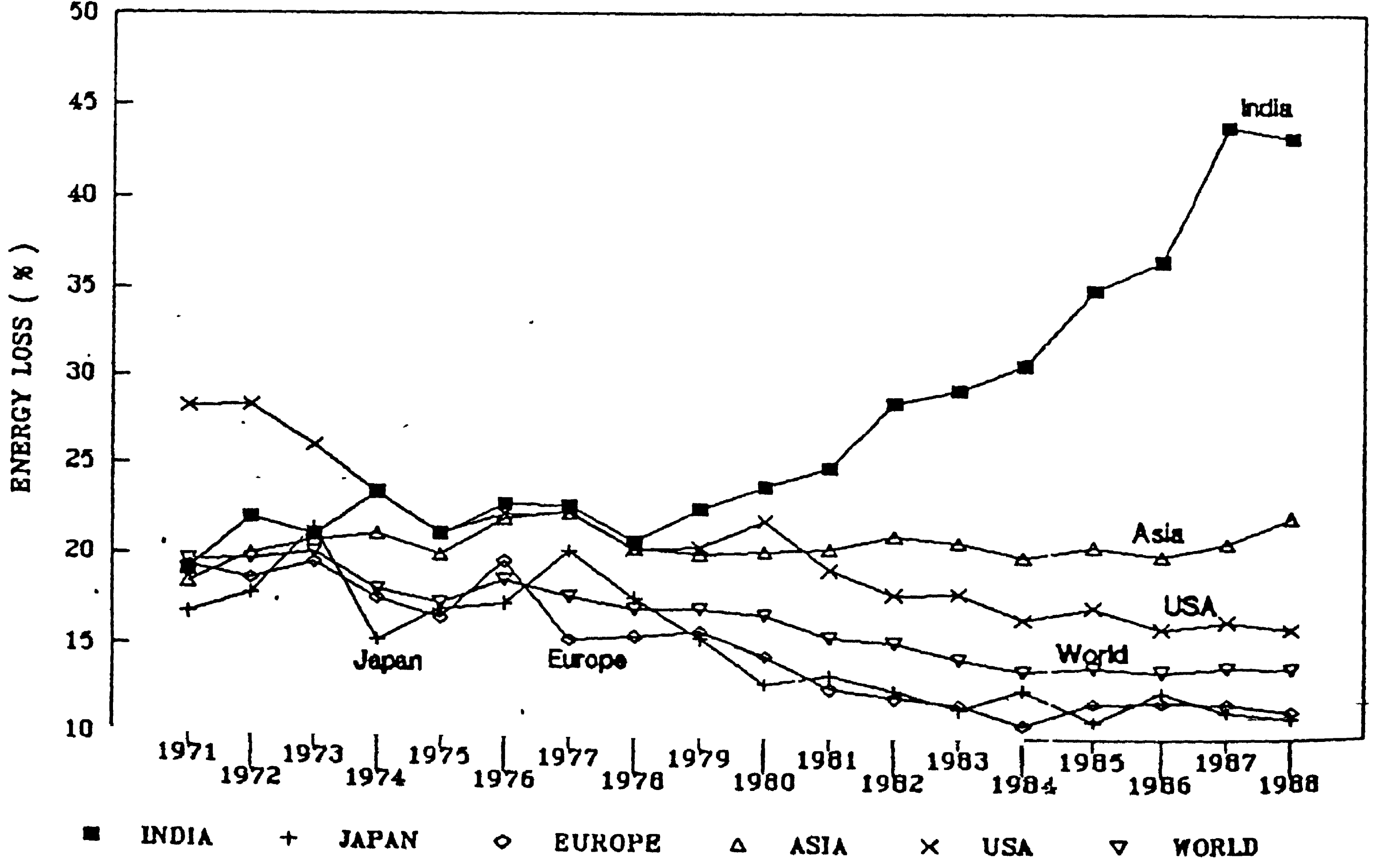
TOTAL LOSS OF ENERGY (%)

Fig. 6



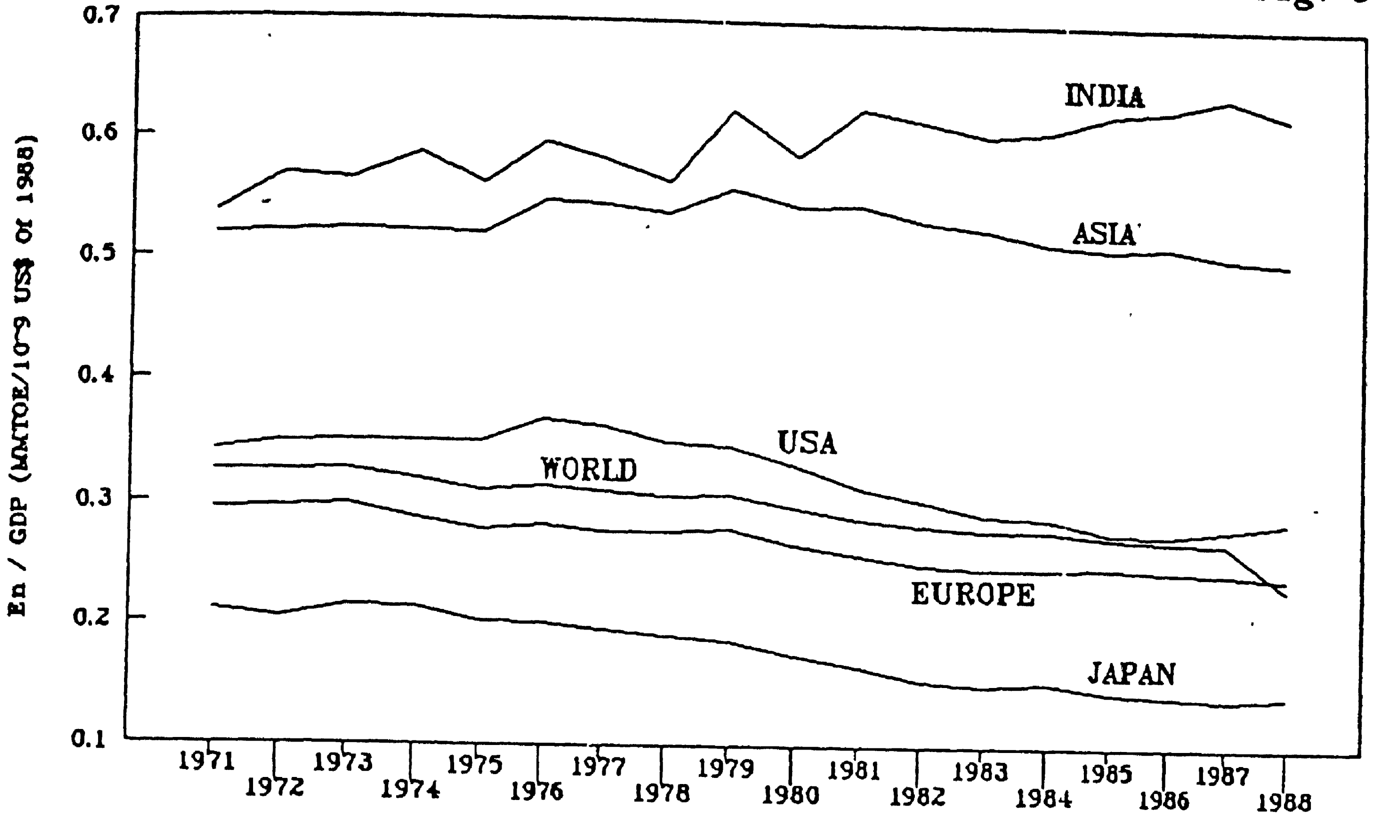
LOSS OF ELECTRICAL ENERGY (%)

Fig. 7



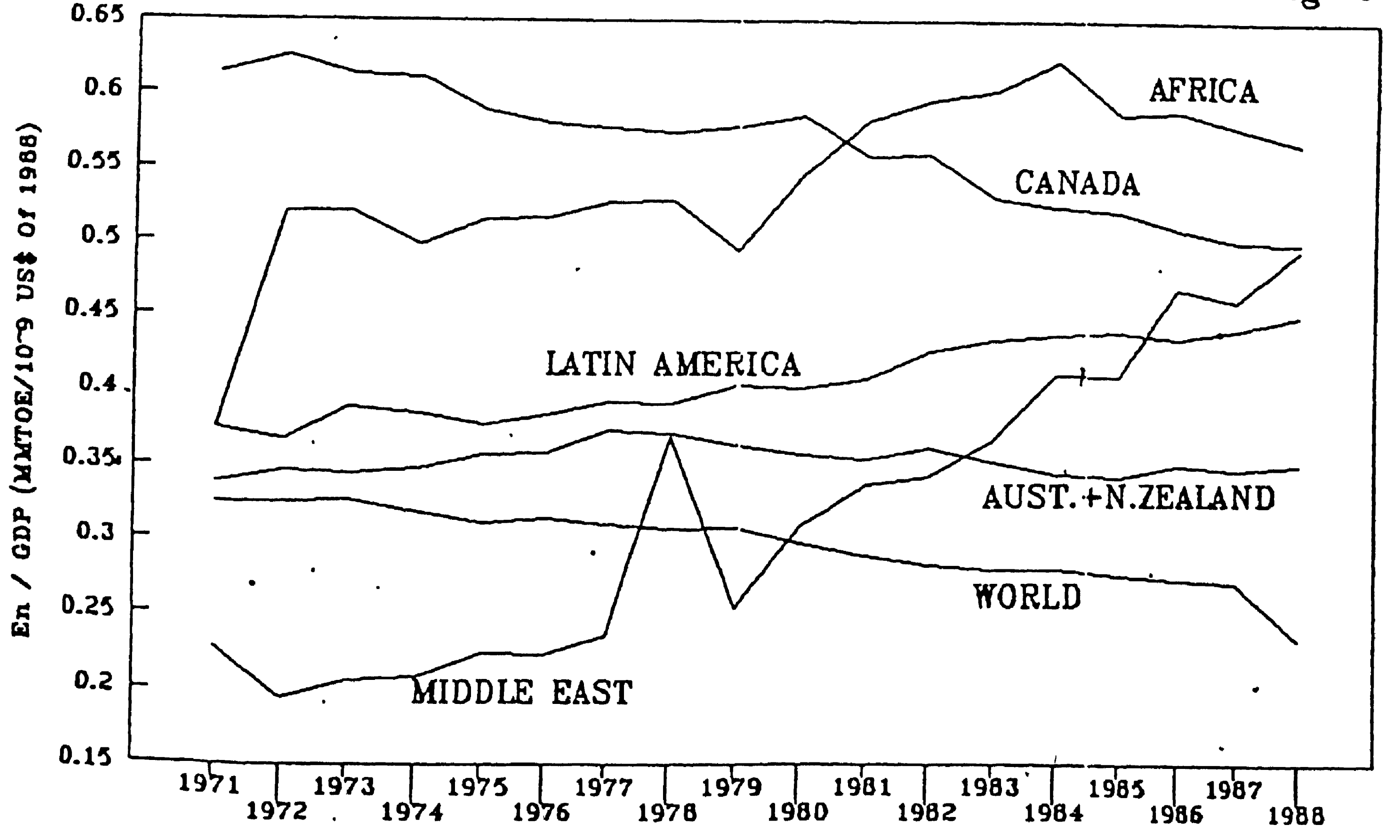
ENERGY REQUIREMENT PER UNIT GDP

Fig. 8



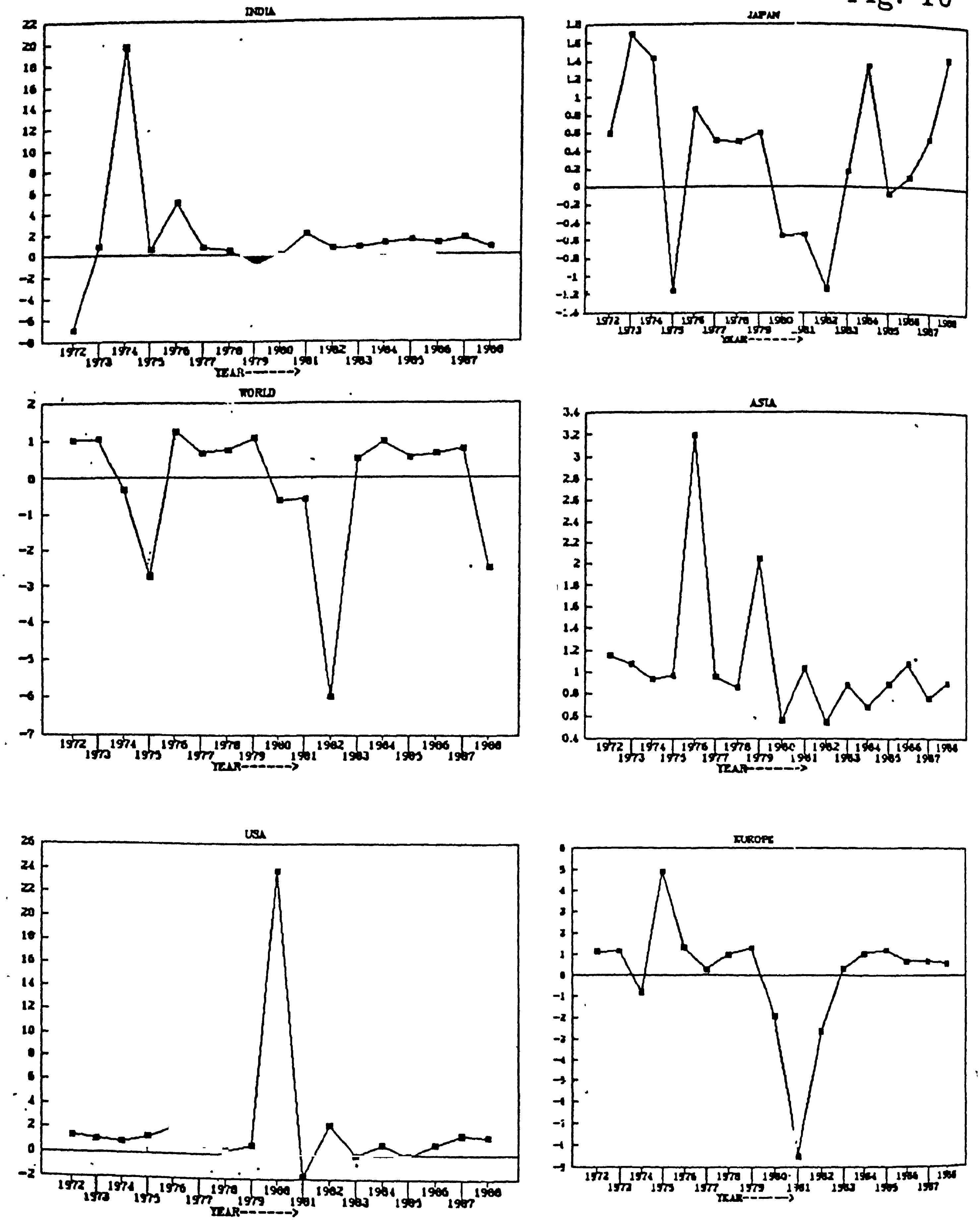
ENERGY REQUIREMENT PER UNIT GDP

Fig. 9



ENERGY - GDP ELASTICITY

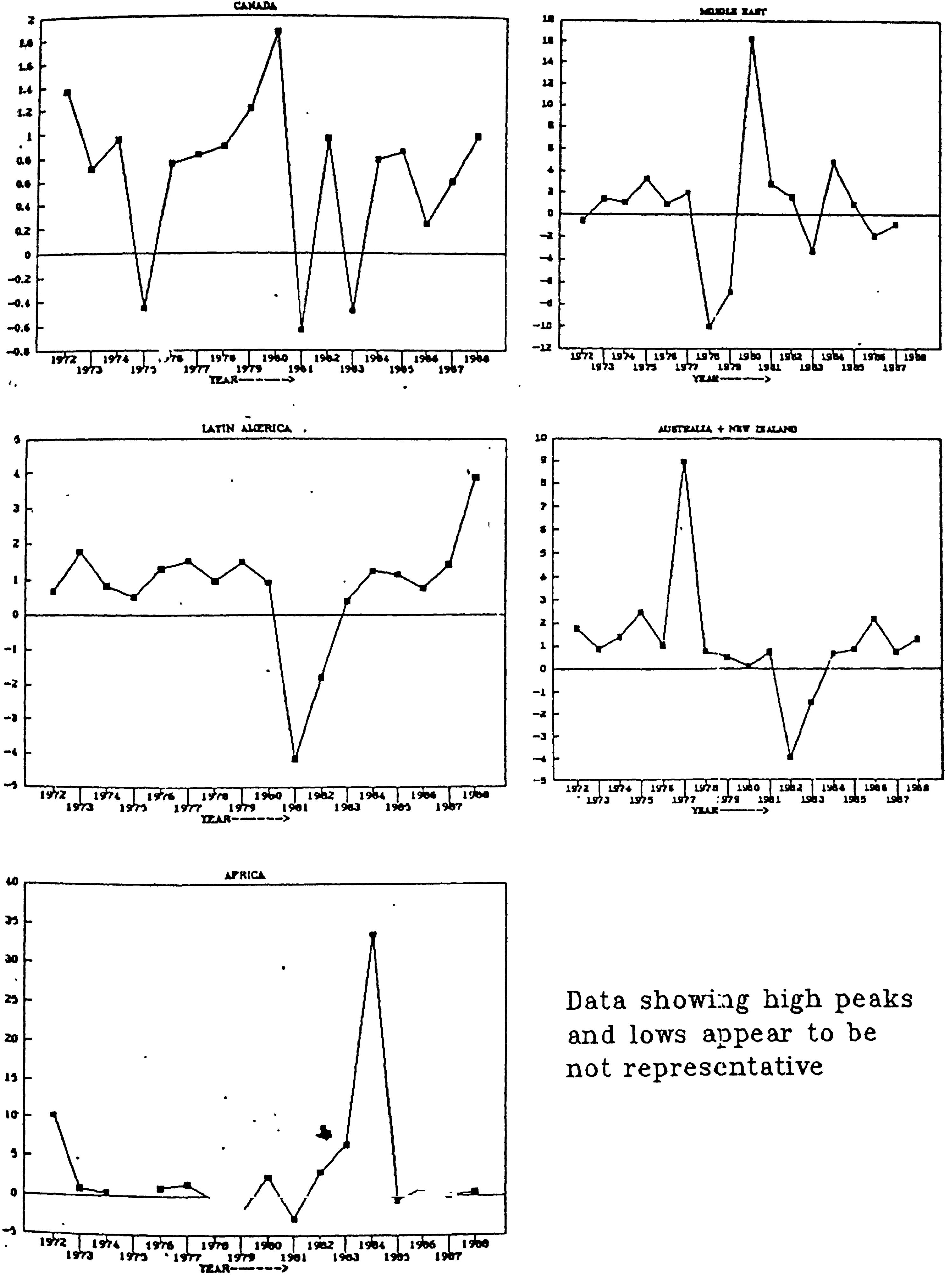
Fig. 10



Data showing high peaks and lows appear to be not representative

ENERGY-GDP ELASTICITY

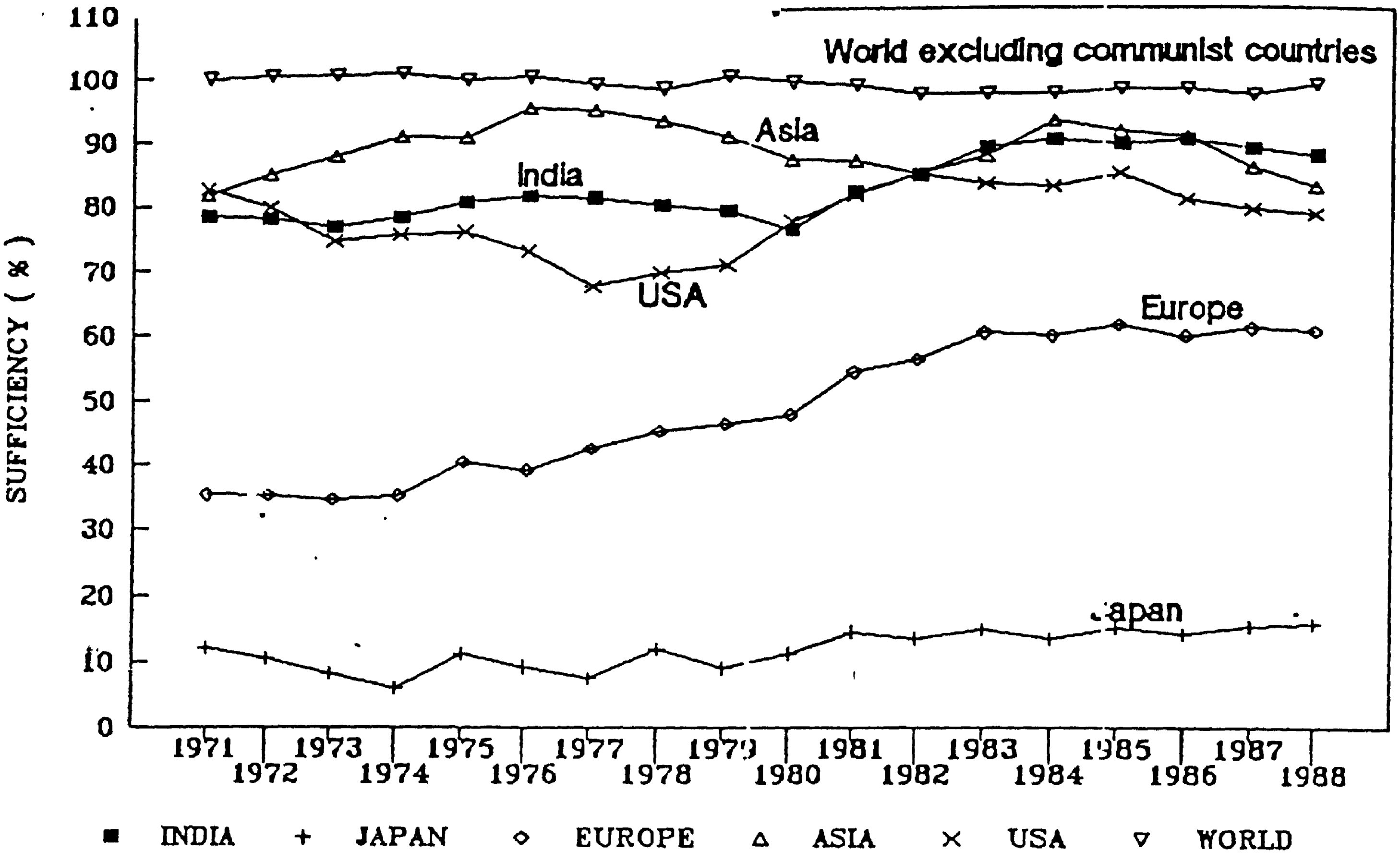
Fig. 11



Data showing high peaks and lows appear to be not representative

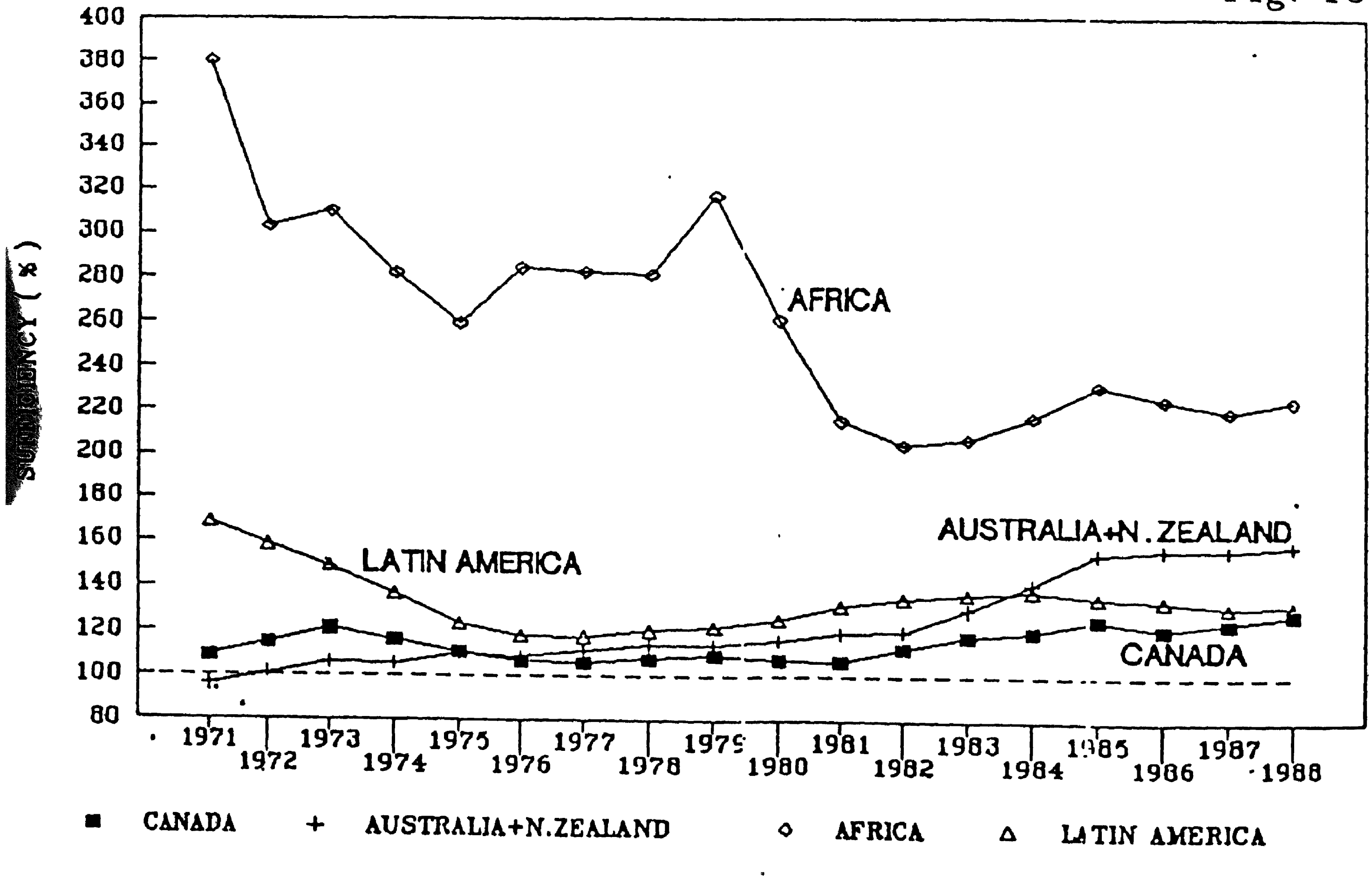
SELF SUFFICIENCY IN ENERGY REQUIREMENT

Fig.12



SELF SUFFICIENCY IN ENERGY REQUIREMENT

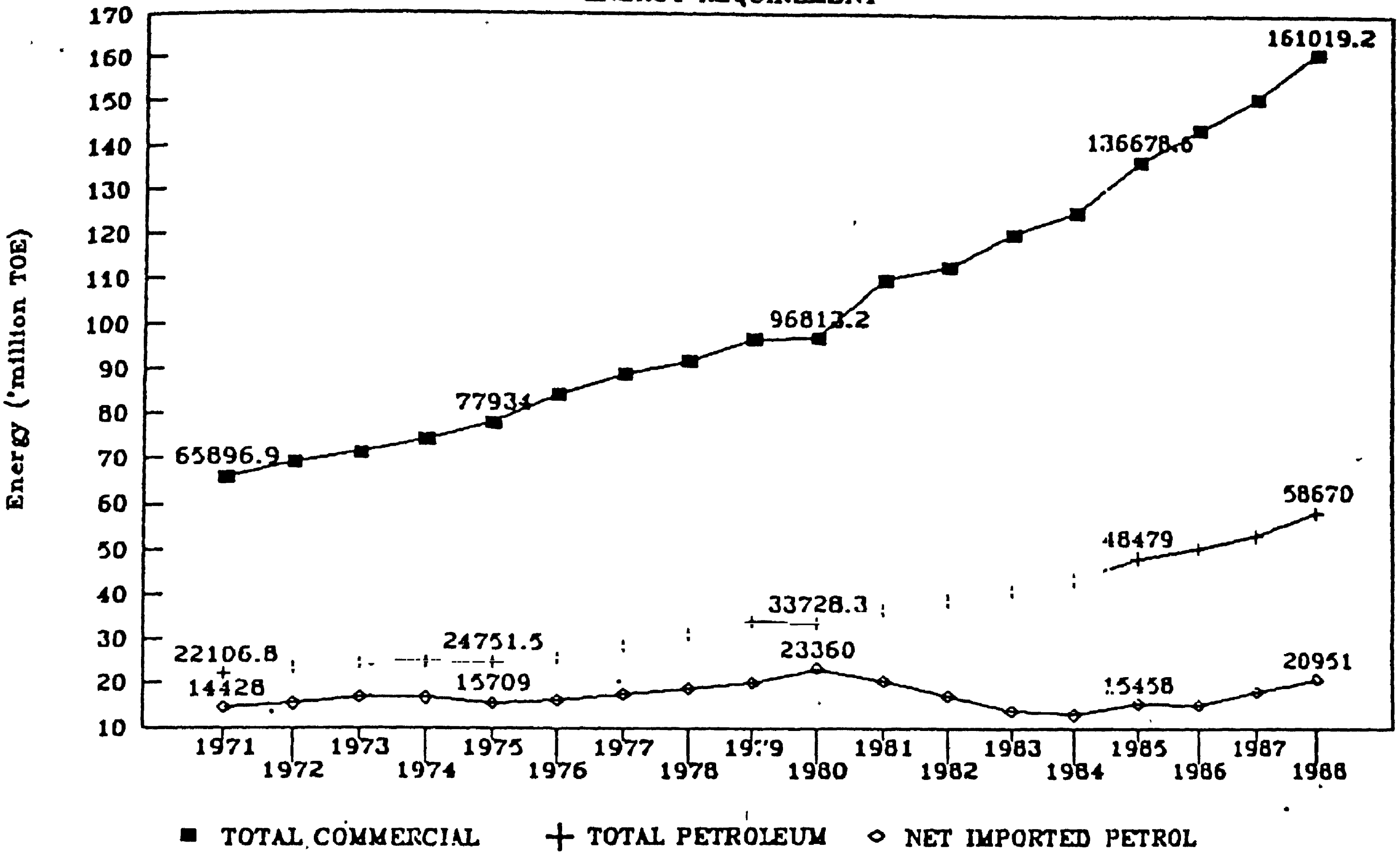
Fig. 13



INDIA

Fig. 14

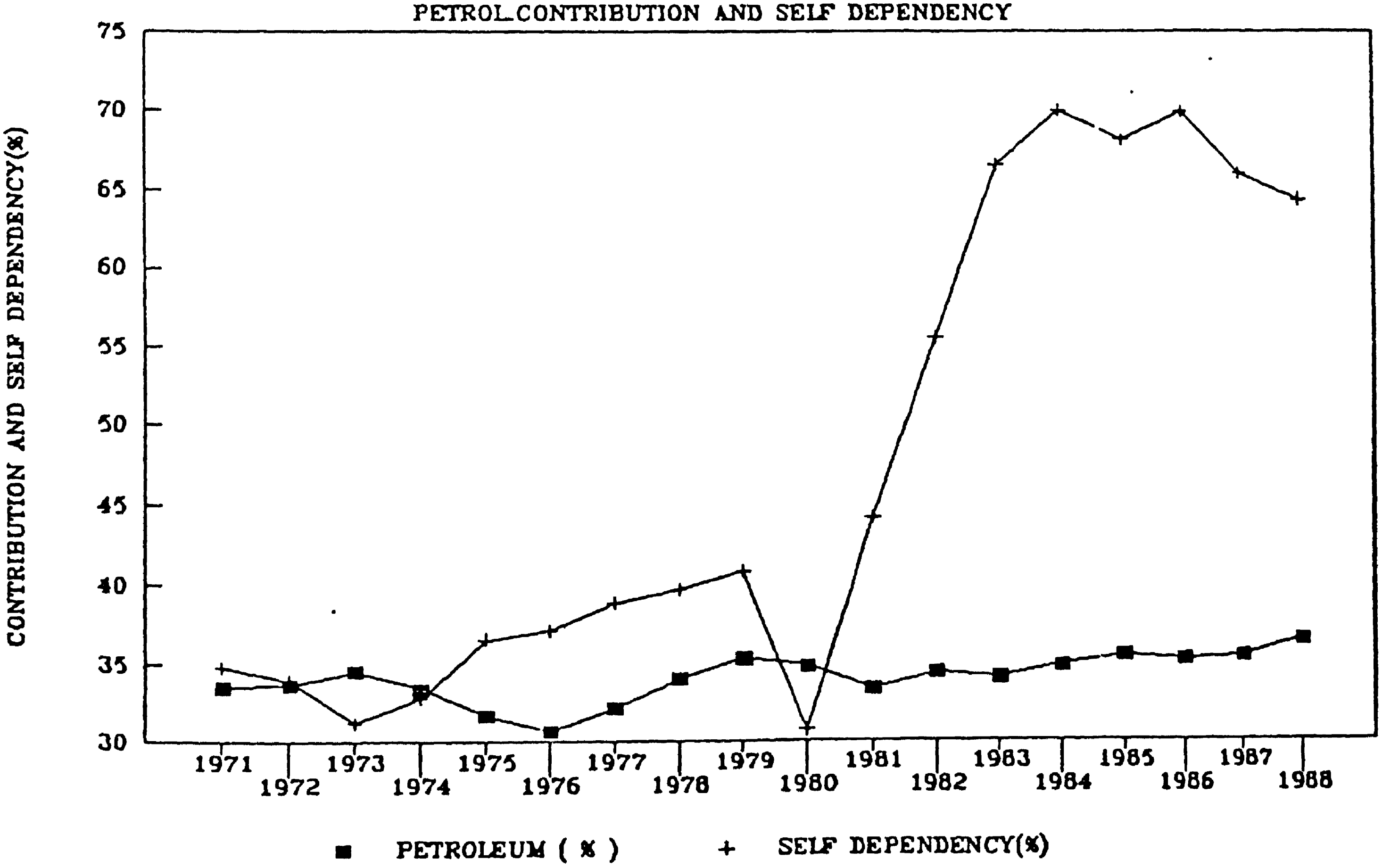
ENERGY REQUIREMENT



INDIA

Fig. 15

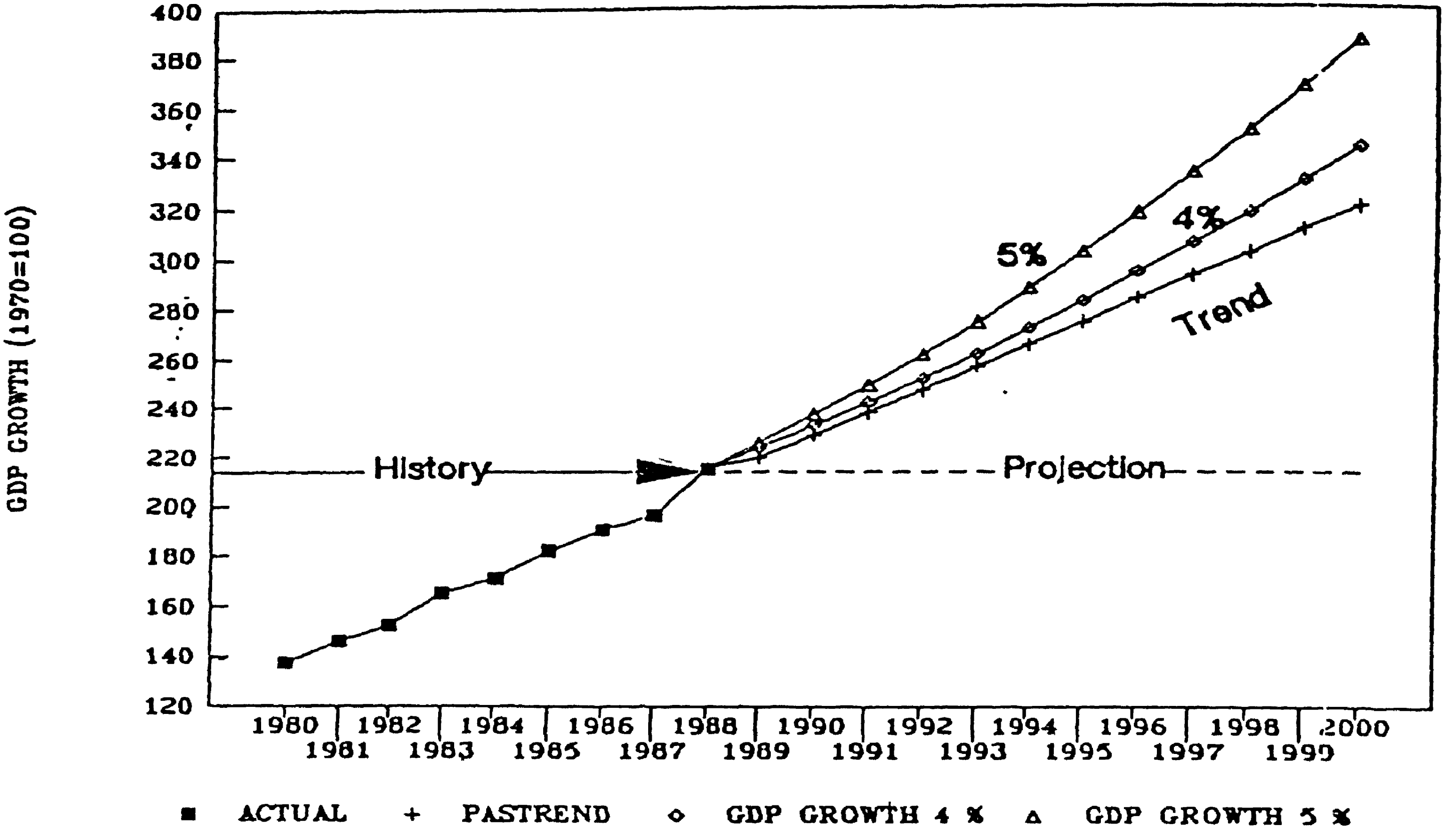
PETROL CONTRIBUTION AND SELF DEPENDENCY



I N D I A

Fig. 16

FUTURE GDP GROWTH



I N D I A

Fig. 17

FUTURE GDP GROWTH

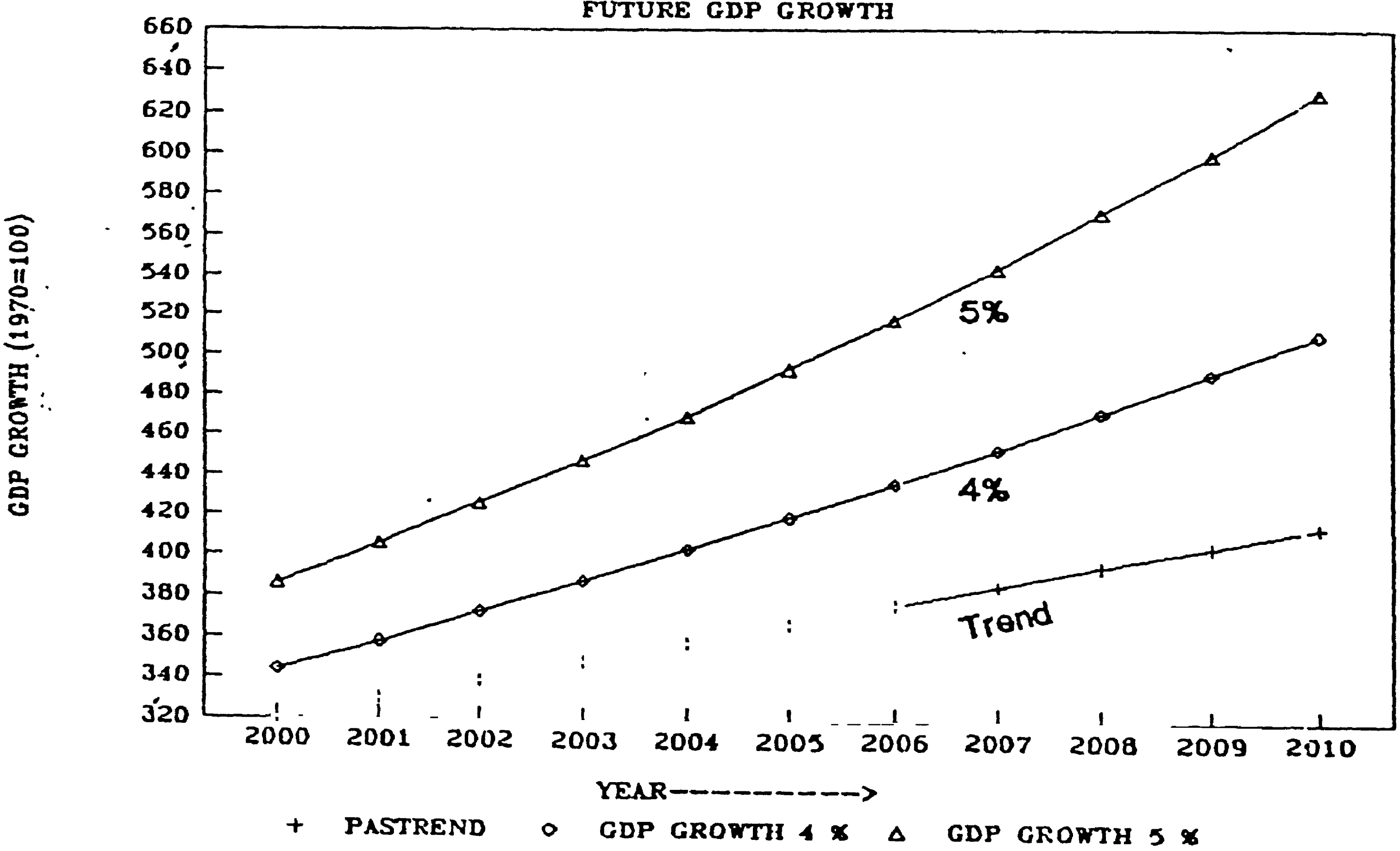


Fig. 18

INDIA

FUTURE ENERGY REQUIREMENT

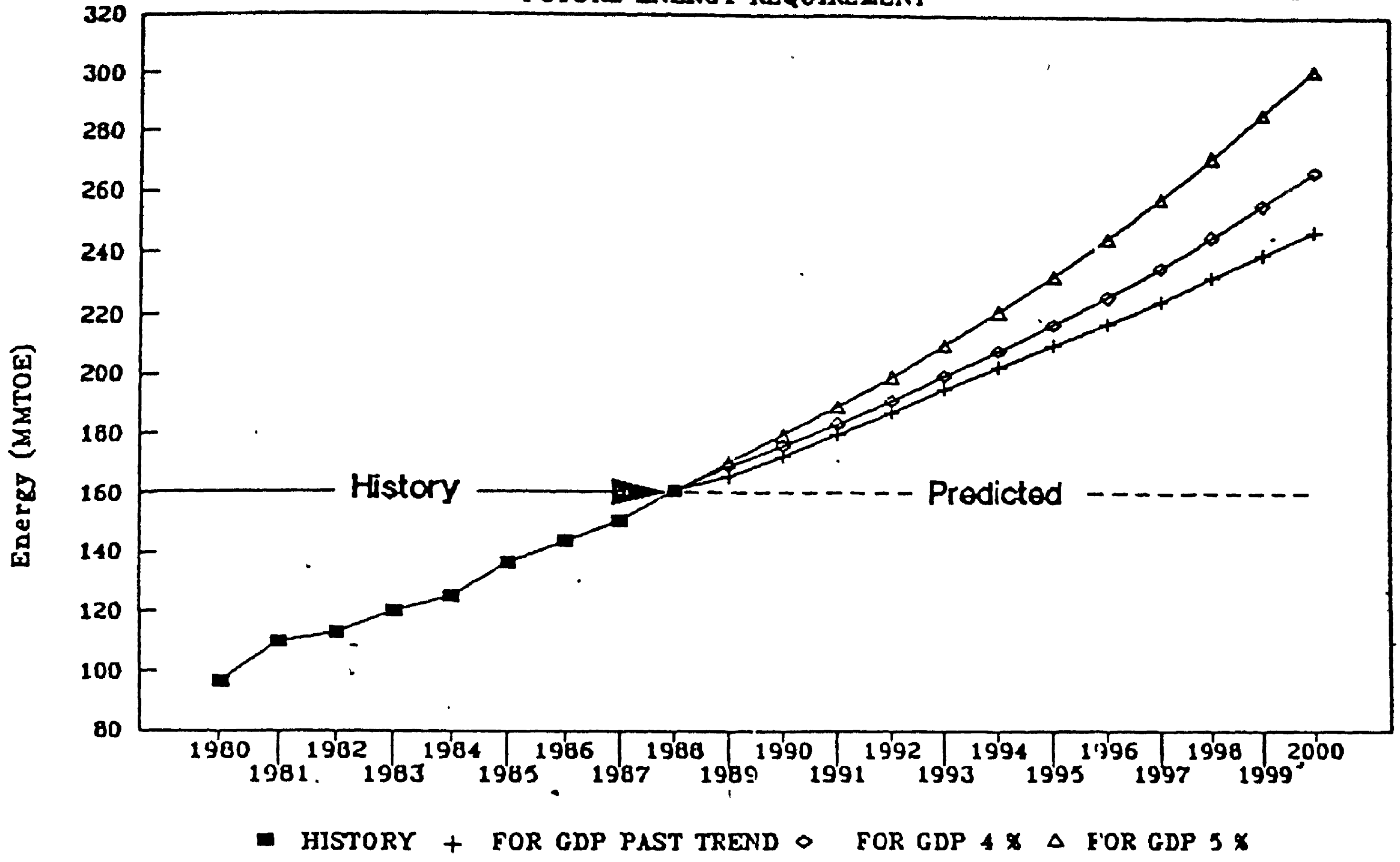


Fig. 19

INDIA

FUTURE ENERGY REQUIREMENT

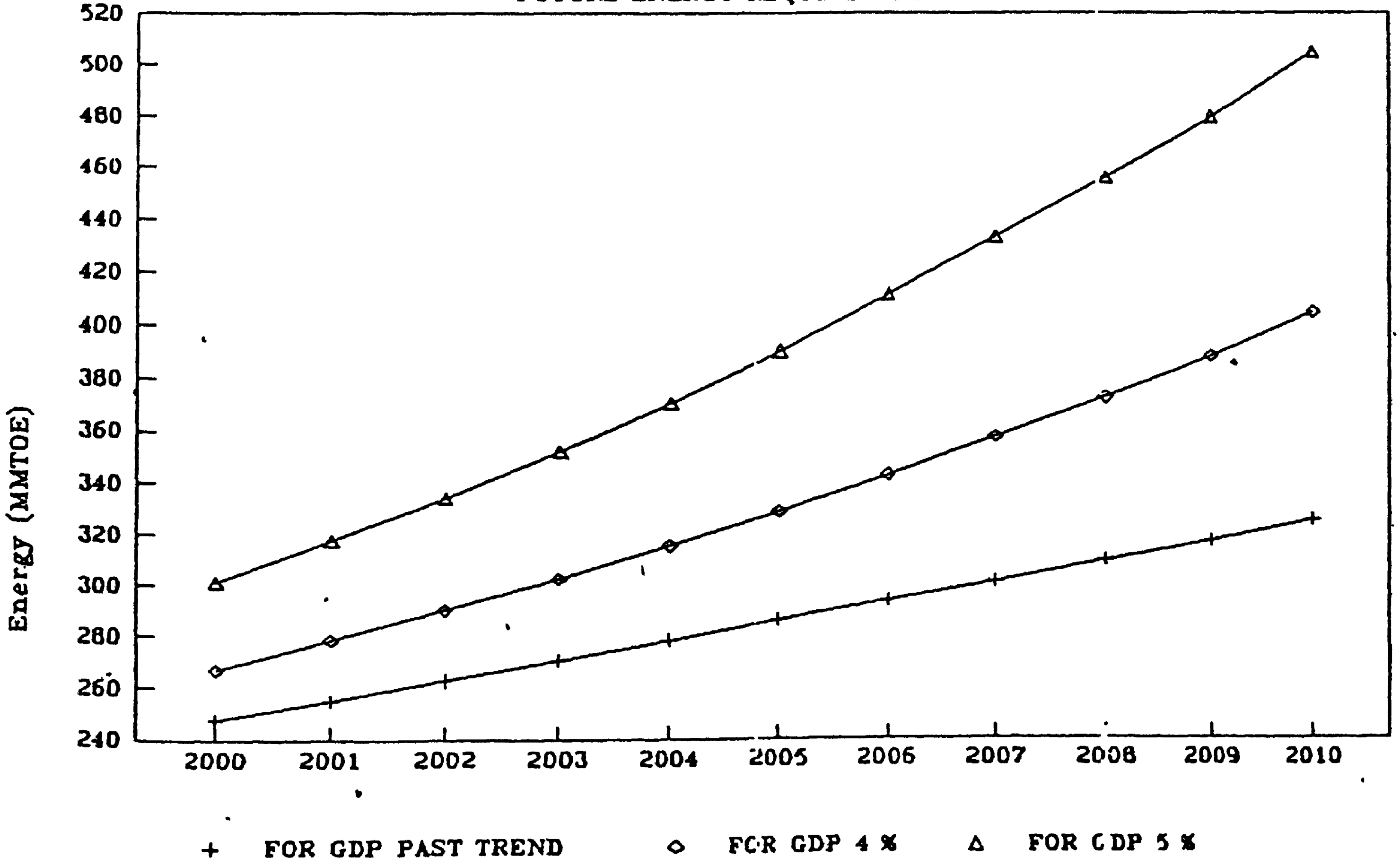


Fig. 20

I N D I A

FUTURE ENERGY REQUIREMENT

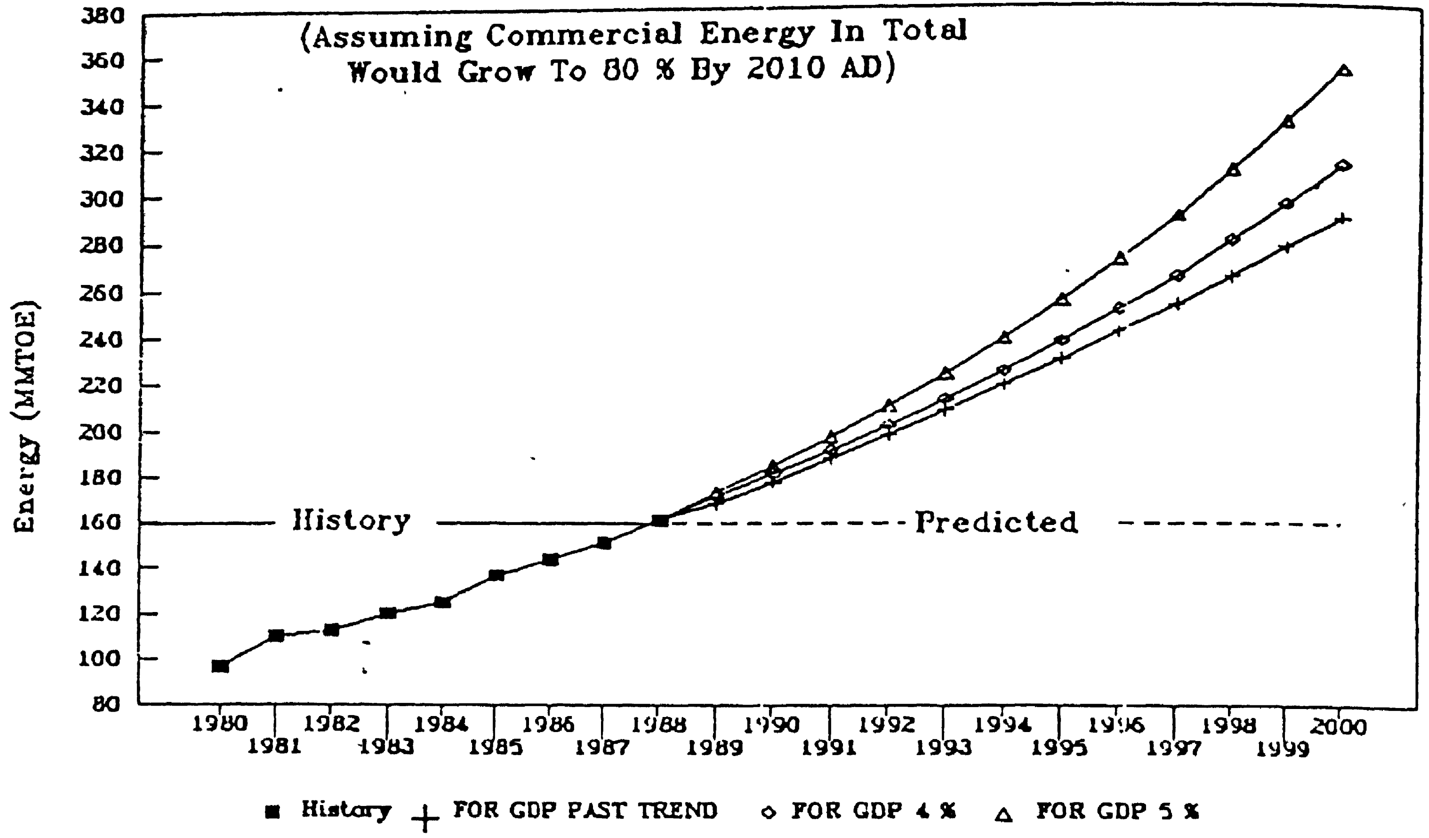
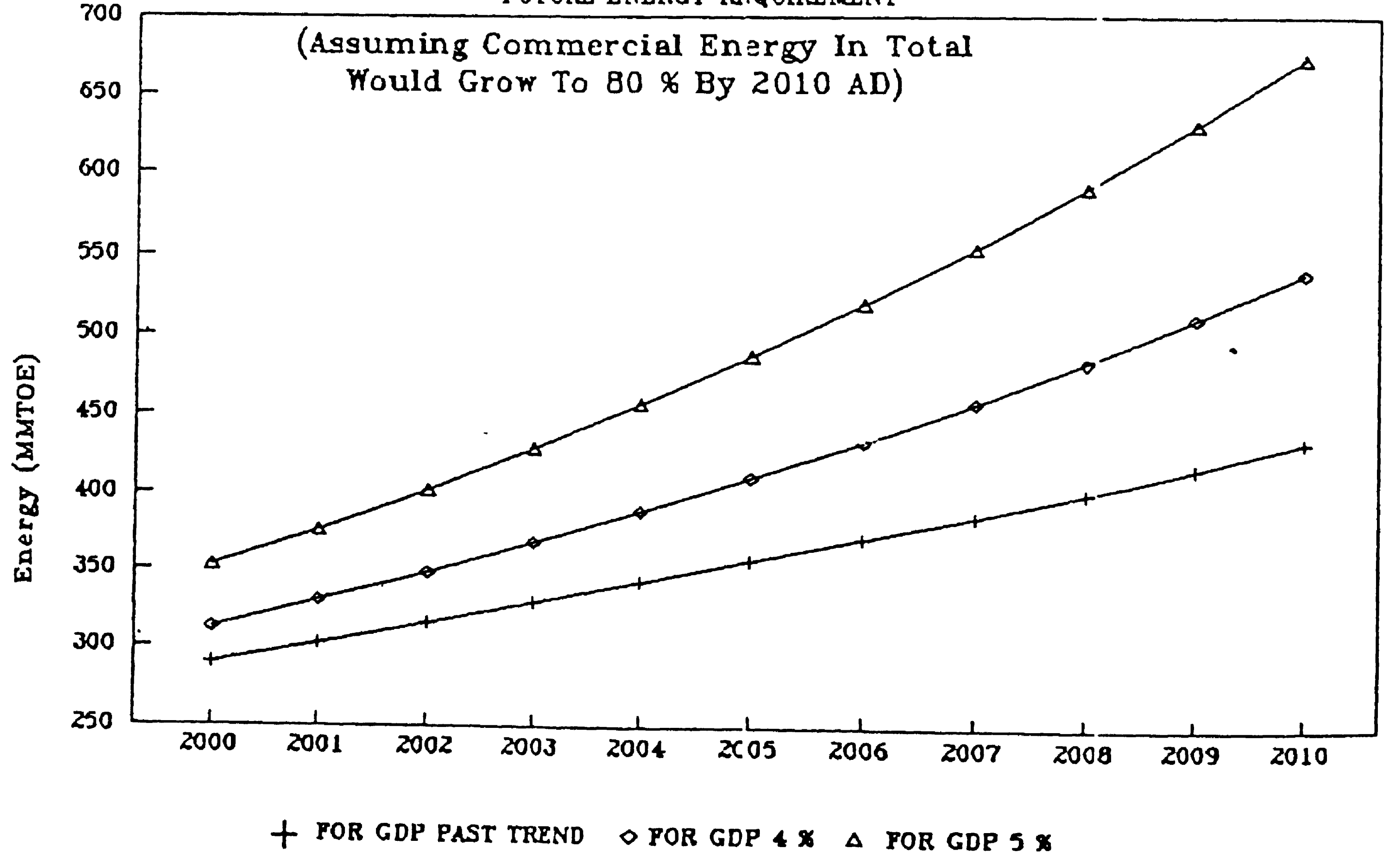


Fig. 21

I N D I A

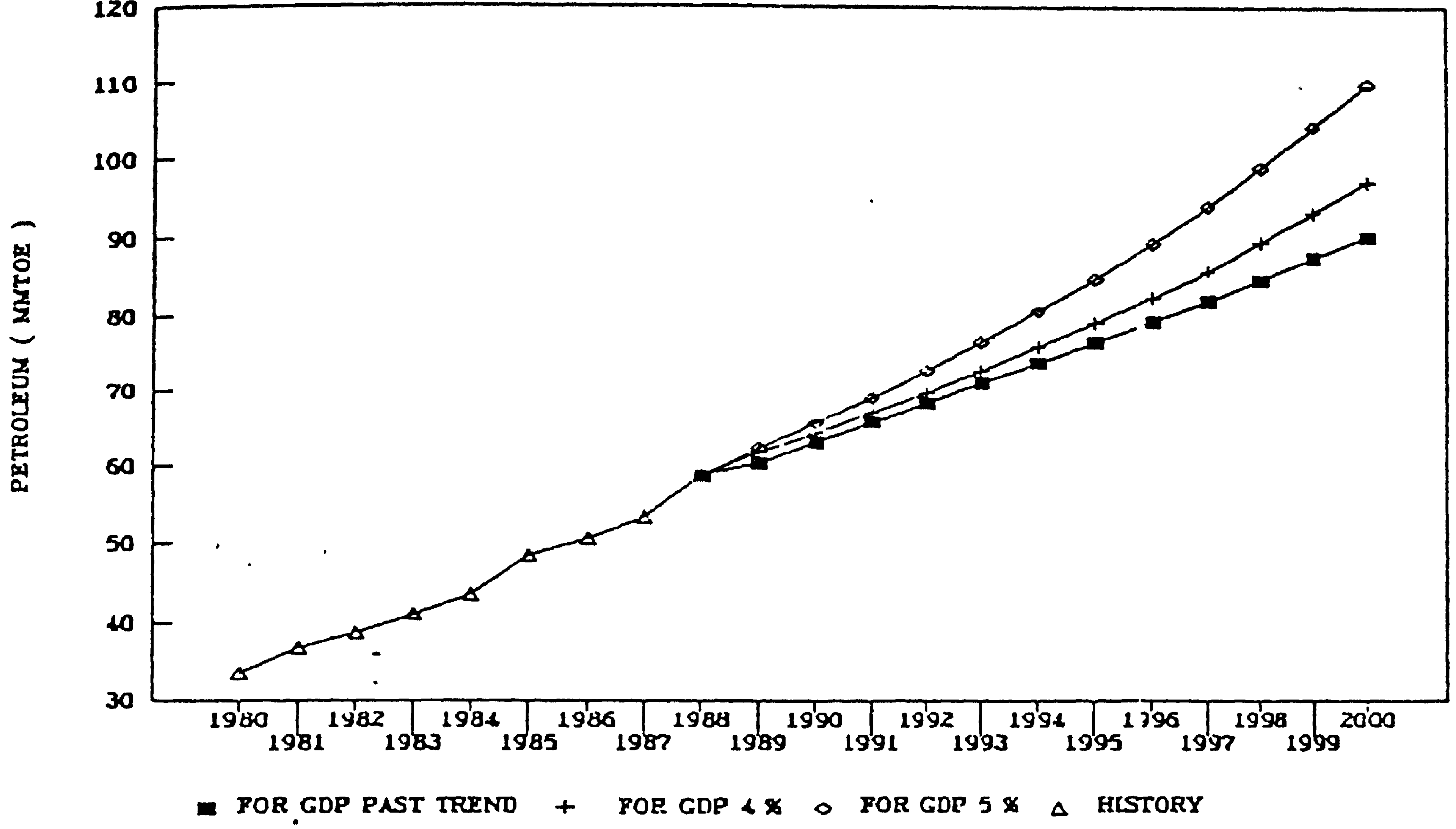
FUTURE ENERGY REQUIREMENT



I N D I A

Fig. 22

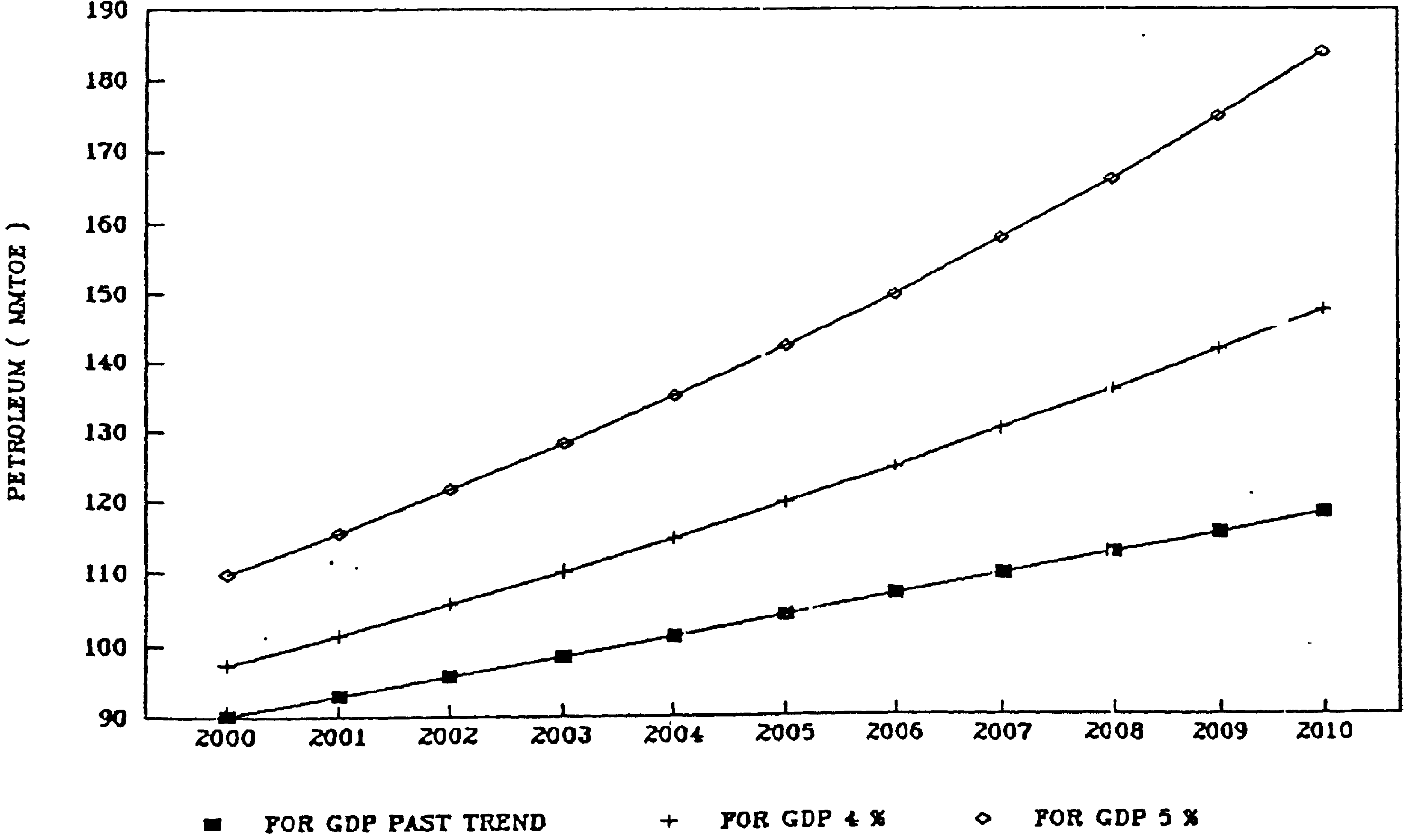
PETROLEUM REQUIREMENT



I N D I A

Fig. 23

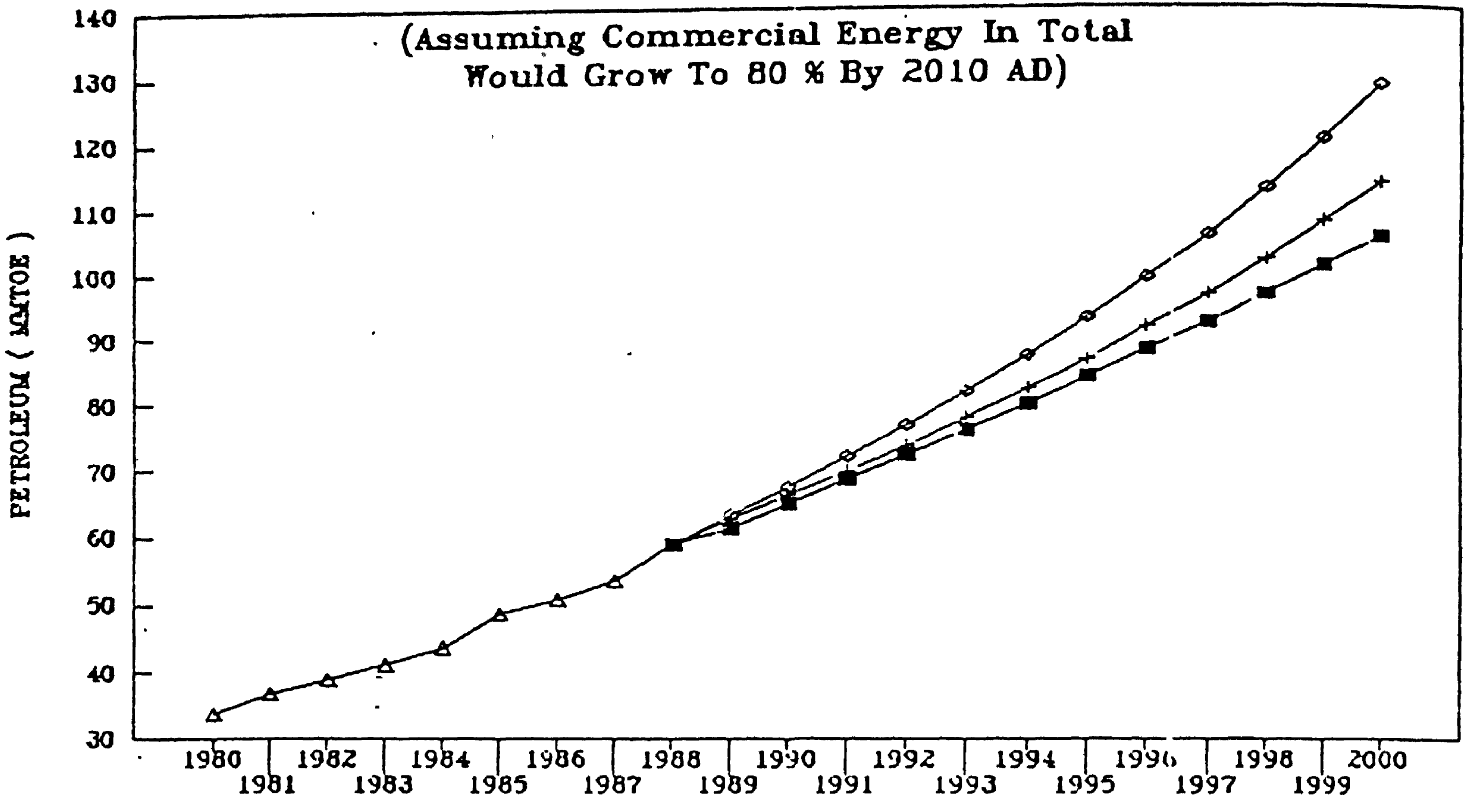
PETROLEUM REQUIREMENT



INDIA

PETROLEUM REQUIREMENT

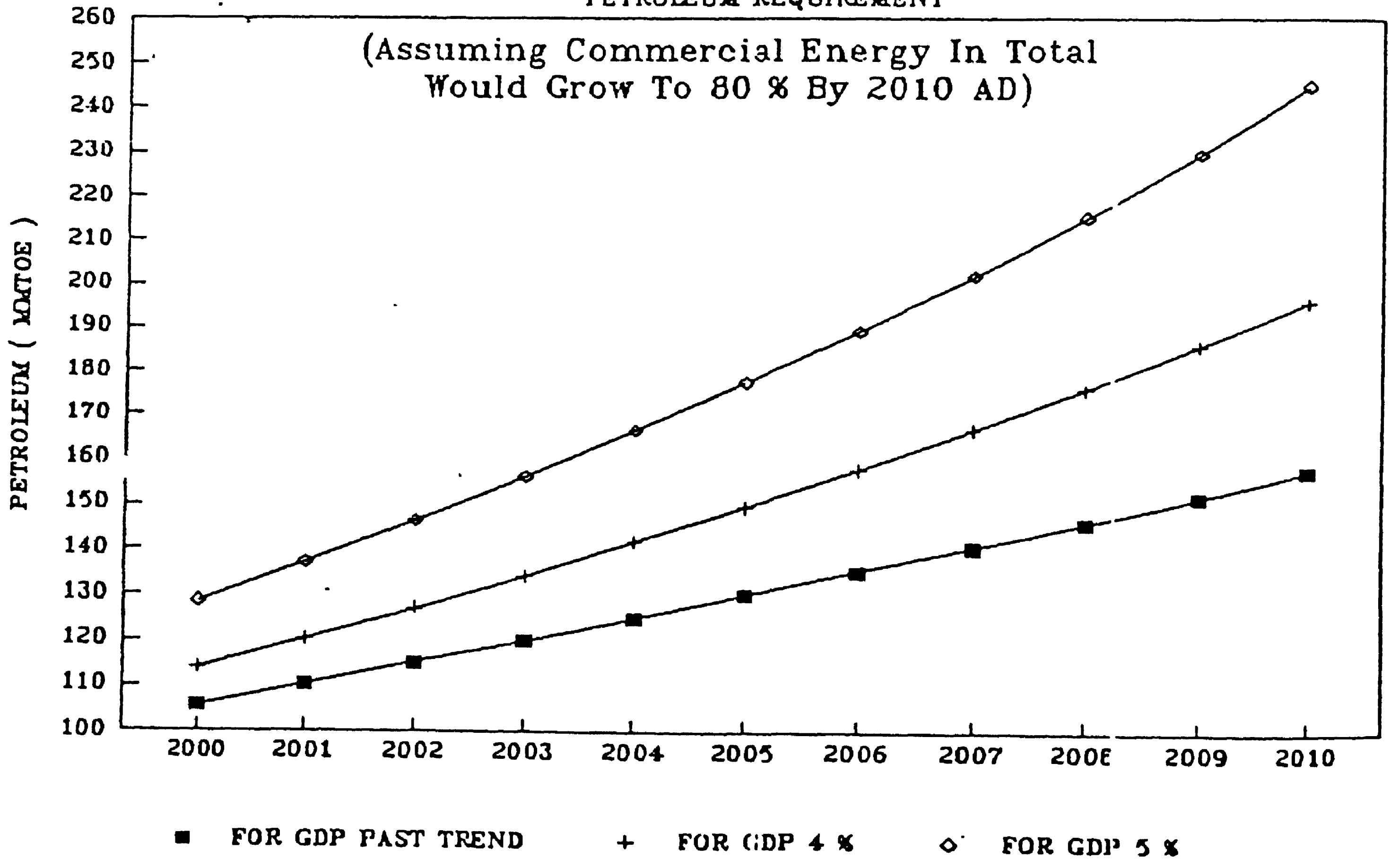
Fig. 24



INDIA

PETROLEUM REQUIREMENT

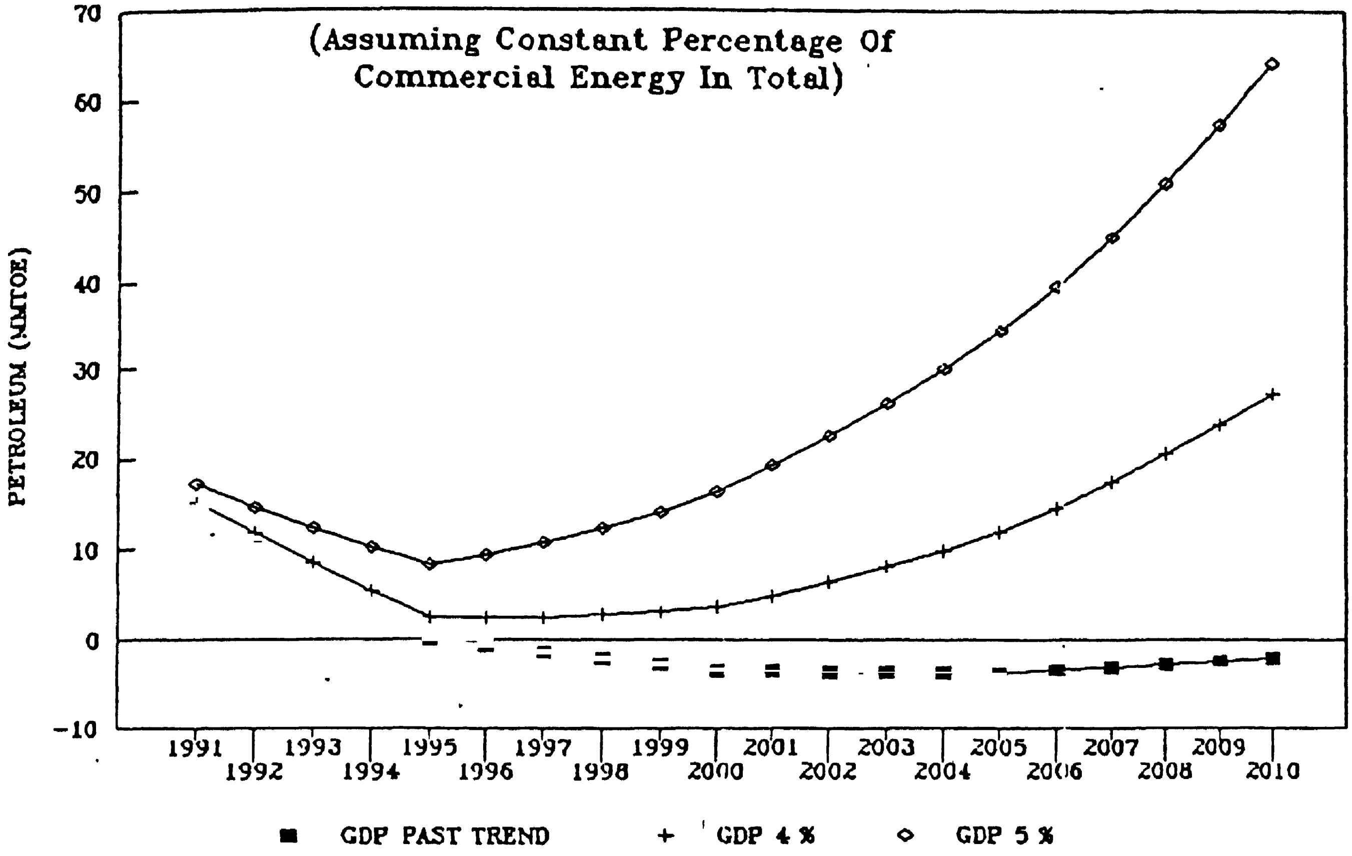
Fig. 25



I N D I A

IMPORT OF PETROLEUM

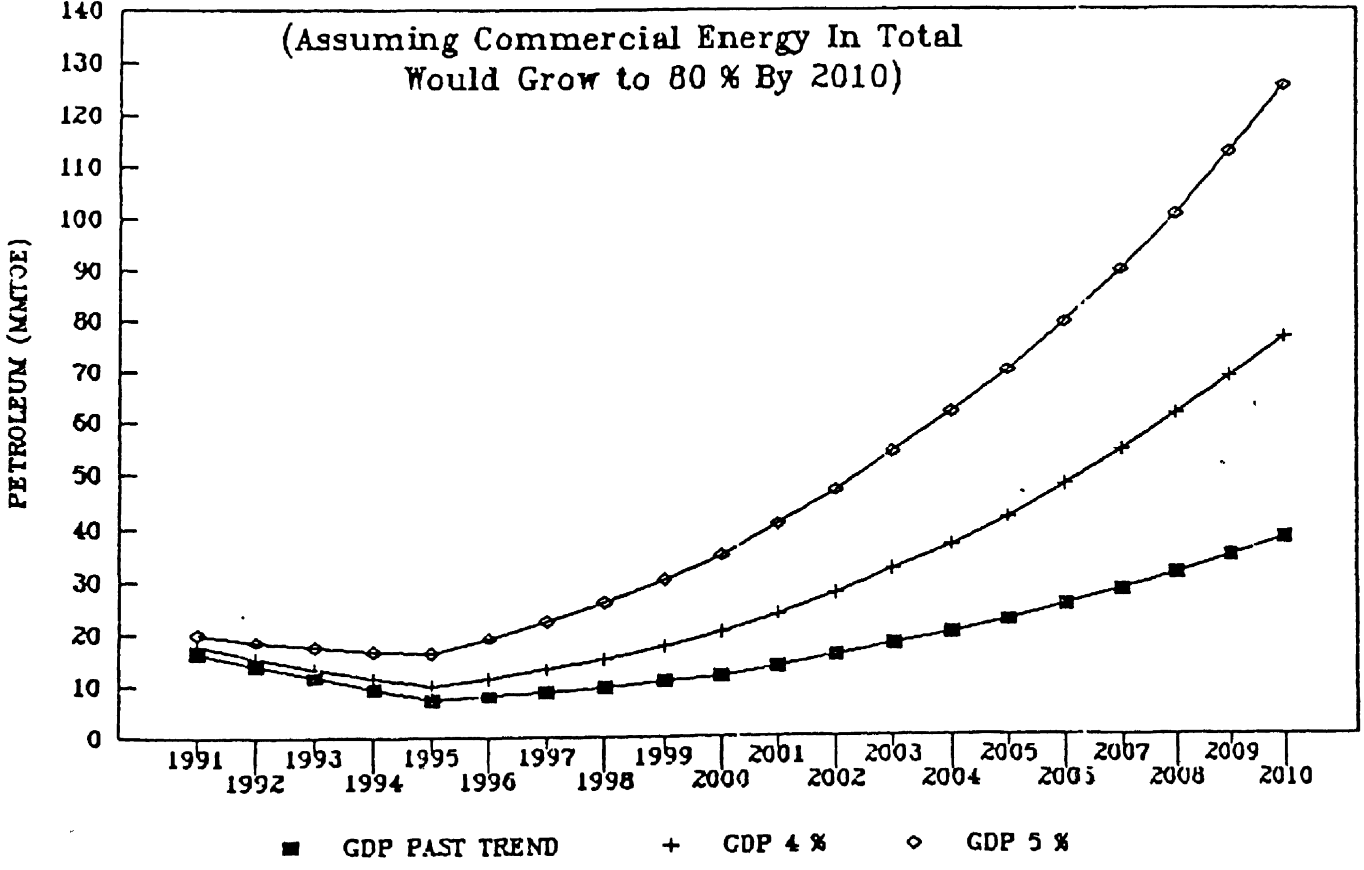
Fig. 26



I N D I A

IMPORT OF PETROLEUM

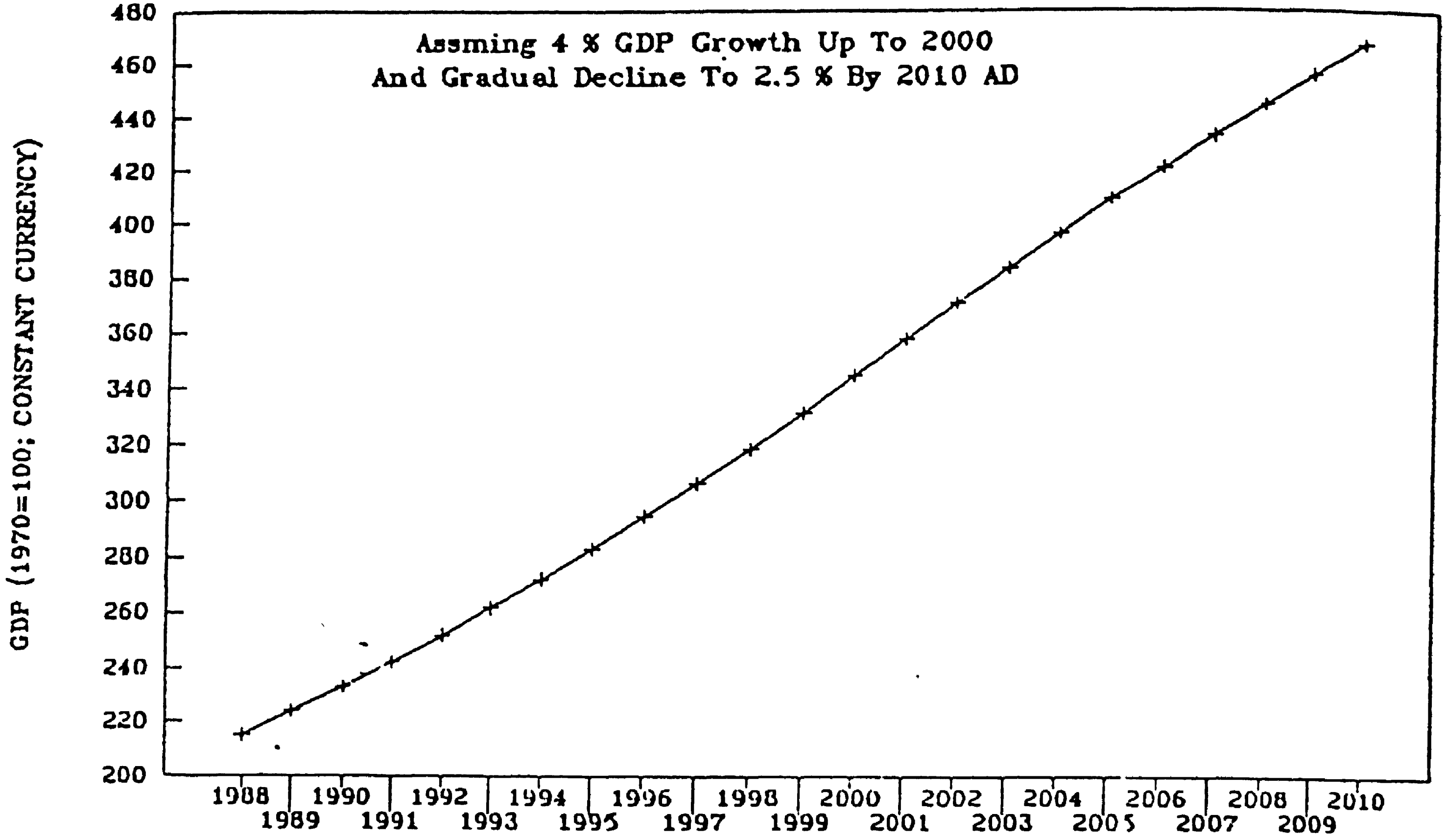
Fig. 27



I N D I A

GDP GROWTH

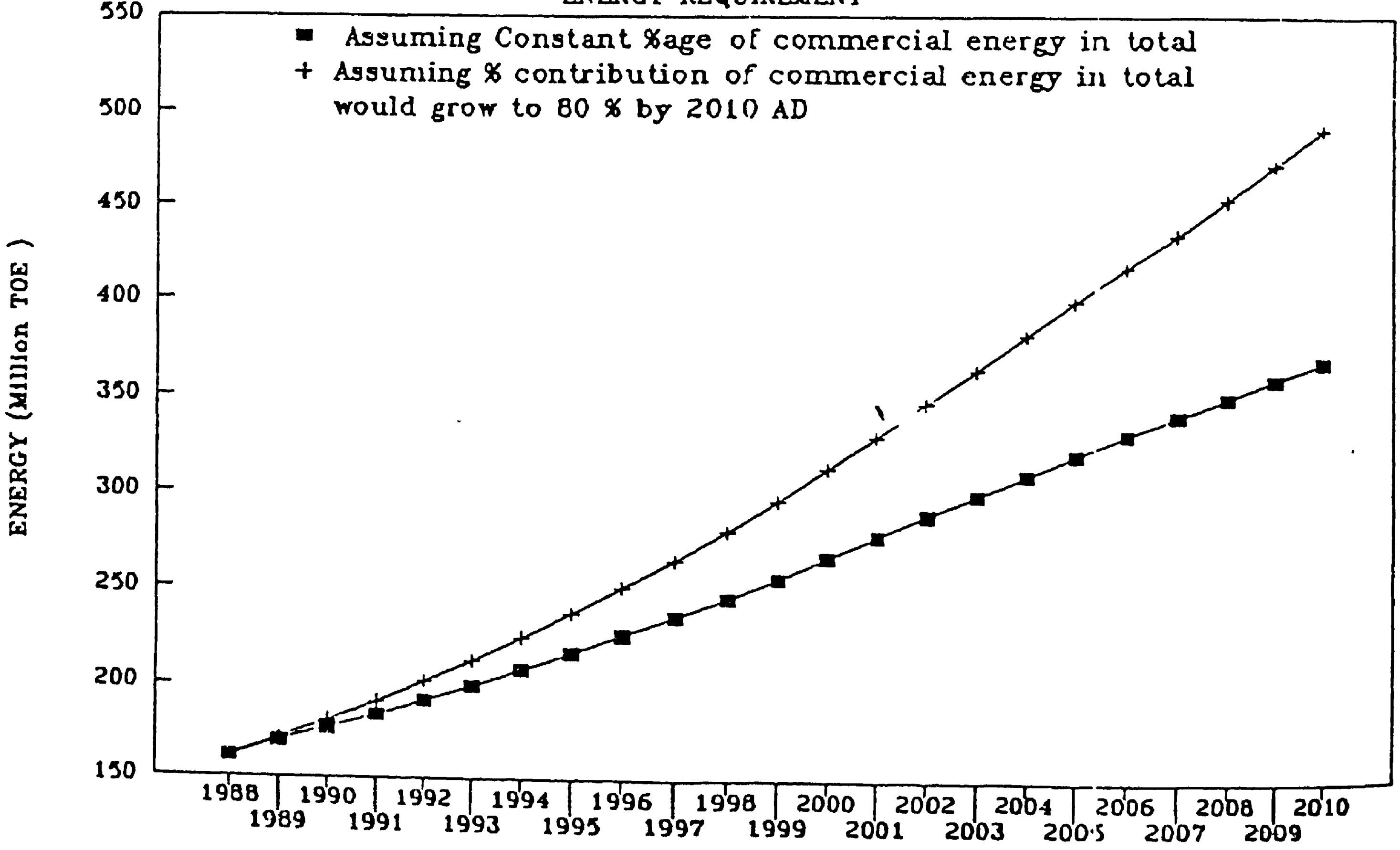
Fig. 28



I N D I A

ENERGY REQUIREMENT

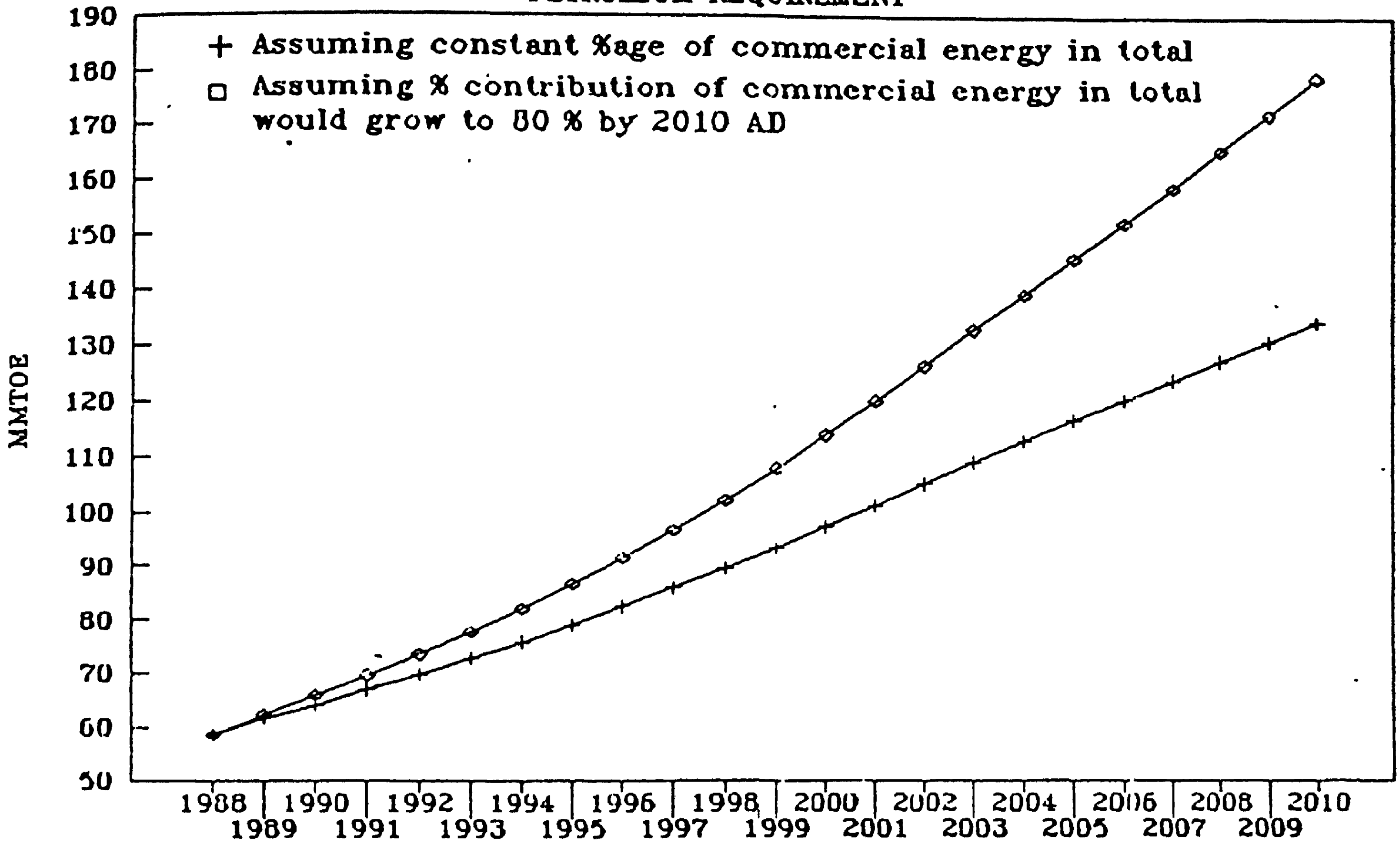
Fig. 29



INDIA

Fig. 30

PETROLEUM REQUIREMENT



INDIA

Fig. 31

IMPORT OF PETROLEUM

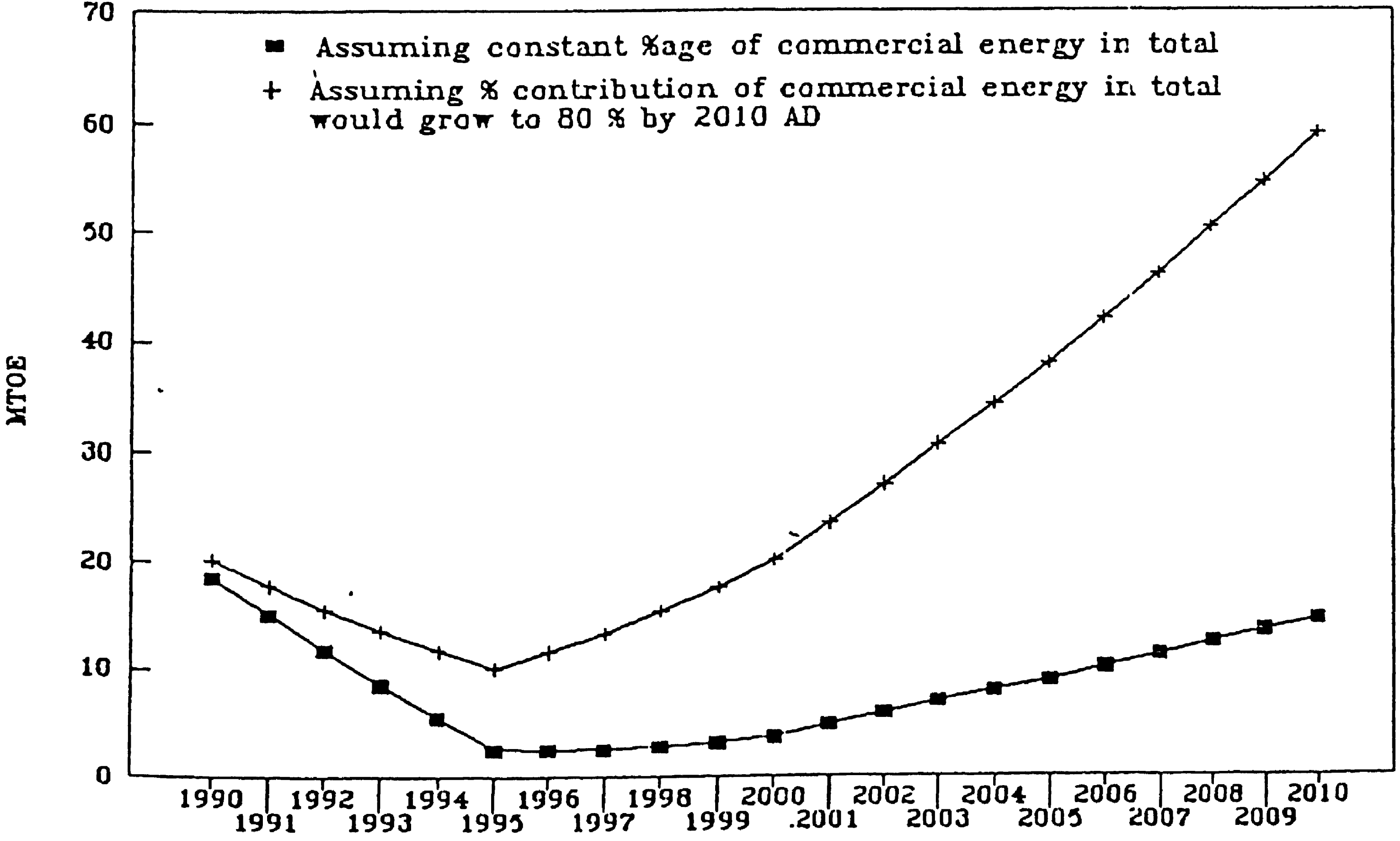
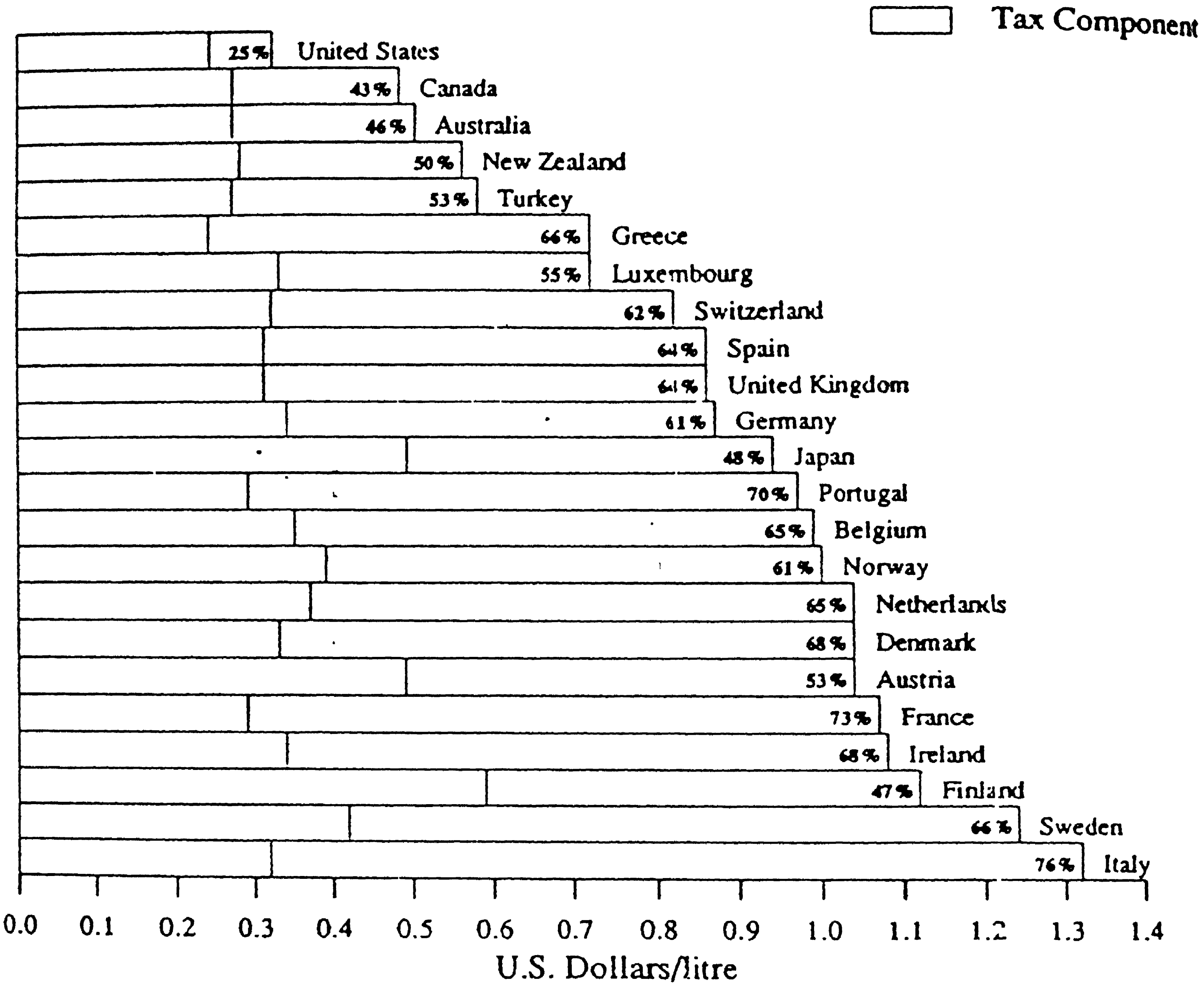


Figure 32: OECD - Gasoline Prices and Taxes (U.S. Dollars/litre)
Third Quarter 1990



India and the Montreal Protocol

Dr. Ajay Mathur

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Background Paper for the
Training Programme for IAS Officers
Conducted by the
Tata Energy Research Institute, New Delhi

September 12-16, 1994

India and the Montreal Protocol

The **Montreal Protocol for the Phaseout of Substances that Deplete the Ozone Layer** represents the first international commitment to consciously phaseout the use of an entire class of chemical (manmade) substances for the good of the global environment. This commitment is especially notable because the phaseout has to be achieved in a (rather short) specified time period, and involves substantial costs.

This paper examines the evolution of this commitment, together with science and the politics that contributed to it; and India's response to the Montreal Protocol, both in terms of the international negotiations, and the internal policies and procedures for its implementation. The major achievements brought about as a result of the Montreal Protocol process (both internationally, as well as within the country) are also discussed in the perspective of their bearing on other international agreements to protect the global environment.

The Science of Ozone Depletion

In the early seventies, Prof. Francis Rowland at the University of California, Irvine, noted the presence of trace amounts of the manmade chemical, trichlorofluoromethane (CCl_3F), better known as CFC-11 (or Freon-11), in the composition of all air samples throughout the world. This observation presented to him, 'an interesting scientific puzzle' - what will eventually happen to these man-made molecules which have been released into the atmosphere and had spread globally?

Together with a colleague, Dr. Mario Molina, Prof. Rowland initiated the investigation of atmospheric processes that affected CFCs. They calculated that the altitude at which the CFCs (which are very stable molecules) would finally decompose because of their interaction with the UV (ultra violet) rays from sun would be in the stratosphere (15-30 kms above the earth), within the ozone layer that of effectively blocks the UV radiation incident on the earth. As a result of this decomposition, the chlorine in the CFCs would be released in the form of atomic chlorine (which is very reactive), which would, in turn, react with the ozone molecules (O_3) in the ozone layer. As a result, the ozone is decomposed into molecular oxygen (O_2) through the formation of an intermediate chemical species, ClO (see box 1 for the chemistry of CFC-ozone interaction).

These calculations lead Molina and Rowland to predict that the steady release of CFC molecules into the atmosphere would eventually lead to a loss of 7 to 13% of global ozone, and they called for a halt to further emissions of CFCs (Molina and Rowland, 1974: Rowland and Molina 1975)

Outline of CFC-Ozone Interaction Chemistry

The ozone layer is formed because of the reaction of the ultra violet (uV) rays from the sun with oxygen molecules in the atmosphere:

O_2 + UV ----> O + O (1)
O + O_2 + M ----> O_3 + M (2)
O_3 + UV ----> O + O_2 (3)

(The M in reaction (2) symbolizes a third molecule, any molecule, that must be involved in this collision)

The reactions (1) and (3) result in the absorption of UV rays 15-30 kms above the earth; consequently the O_2 - O_3 reactions and the formation of ozone molecules (O_3) prevents UV rays from reaching the earths' surface.

CFC-11 (CCl_3 F) and CFC-12 (CCl_2 F_2) are very stable compounds that do not normally react and breakdown into their constituent elements in the lower atmosphere - in current environmental terms, they are "non-biodegradable". Consequently, they slowly diffuse through the entire atmosphere, and rise to great altitudes as well. At altitudes above 15 kms, the energy of the UV-rays (particularly the UV-C rays) from the sun is adequate to decompose them:

CCl_3 F + UV-C ----> Cl + CCl_2F (4)

CCl_2 F_2 + UV-C ----> Cl + $CClF_2$ (5)

The atomic chlorine reacts with the ozone molecules and the atomic oxygen in the ozone layer (which is largely in a band at altitudes between 15 and 30 kms) to form molecular oxygen:

Cl + O_3 ----> ClO + O_2 (6)

ClO + O ----> Cl + O_2 (7)

O + O_3 ----> $2O_2$ (8)

Since the usual reaction of O atoms involves the formation of O_3 by (2), the effect of (8) is really equivalent to the removal of **two** ozone molecules. In addition, the atomic chlorine liberated from CFC-decomposition is available again after (7) to decompose another set of ozone molecules. This chain process continues in rapid bursts of ozone removal, and the average number of ozone molecules destroyed by every chlorine atom is eventually about 100,000.

Predictably, their findings lead to an uproar. The link between ozone depletion and increased UV radiation on the earths surface and its deleterious effects on human health, plants, and materials was well known. Consequently, the presence of CFCs at altitudes of 15-30 kms was questioned, as was the proposed chemistry (see box 2) of ozone destruction.

CFCs: the wonder chemicals

It was particularly ironic that the CFCs were found to cause a global environmental problem. CFCs (chlorofluorocarbons) do not exist in nature, and were created, "to specifications". They are chemically inert, and easily converted between gaseous and liquid states at ordinary temperatures. There are three major CFCs - CFC-11, CFC-12, and CFC-113 (CCl_2F CCl F_2). The three-digit numbering nomenclature follows the rule: the first digit is the number of carbon atoms minus one (in case there is one carbon atom, the first digit is zero and is not written); the second digit is the number of hydrogen atoms plus one; and the third digit is the number of fluorine atoms.

CFCs are used as refrigerants in refrigerators and air conditioners; as propellants in aerosol sprays; as foaming agents for blowing foams (for applications in refrigerator insulation, car seats, mattresses, thermoware, etc); and for the cleaning of electronic assemblies.

This versatility in the market-place brought about a steadily increasing demand for CFCs in all countries around the world; CFC use doubled every five to seven years, and approached 1 million tons in 1974 when Molina and Rowland published their hypothesis of CFC-based ozone layer destruction.

An experimental test of the predictions was carried out in 1975 by collecting air samples at different altitudes in the atmosphere through unmanned stratospheric balloon flights sponsored by the US National Academy of Sciences (USNAS). The measured concentrations were in excellent agreement with the predictions of Molina and Rowland (1974).

These tests transformed Prof. Rowland's "interesting scientific puzzle", into a major global environmental problem.

The Effects of Ozone Depletion

The US NAS balloon samples of CFC composition at various altitudes in the atmosphere proved the Rowland-Molina hypothesis relating CFC emissions to ozone depletion. In the years that followed, intensive experimental and analytical research was conducted to measure CFC and ozone concentrations, changes in UV-irradiance, and projected changes due to the continued emissions of CFCs. In the two following sections, the current state of knowledge regarding ozone depletion and impacts of increased UV-radiation are briefly summarized.

CFC-ozone interactions

Since the first global air-composition measurements which showed the ubiquitous presence of CFCs (Lovelock, 1971), measurements have been carried out regularly. Figure 1 shows the concentrations of CFC-11 in surface air samples at different latitudes in 1971, 1979, 1981 and 1990 (Rowland, 1991).

The figure shows that CFC-11 concentration exhibits a North-South gradient. The minimum concentrations are over Antarctica, and have been about 7% lower than the global average. At the same time, the ozone concentration in Antarctica has also been decreasing over the time. Figure 2 shows ozone at Halley Bay, Antarctica, from 1957 to 1984 - the decreasing trend from the mid-seventies is clearly evident.

Based on ozone measurements carried out since 1978 by TOMS (Total Ozone Mapping Spectrometer) abroad the Nimbus 7 satellite, and by ground-based aircraft, the CFC-ozone depletion link has been conclusively proven, particularly by the presence of CFCs and of intermediate chemical species (such as ClO) in the ozone layer. The data also support Figure 1: there is much larger ozone loss in the Southern Hemisphere than in the north. Recently, a similar (through smaller) decrease in ozone levels in the Arctic has also been measured.

The reason for preferential ozone depletion in the polar regions arises because of the very cold temperatures that enhance the formation of PSCs (polar stratospheric clouds, which are condensed forms of ice crystals). The strong circumpolar vortex over Antarctica results in a very high frequency of occurrence of PSCs in that region; much more than in the Arctic. Ozone loss is found to be initiated by chemical reactions on the surface of PSCs which convert the long-lived chlorine into chemically more reactive forms that destroy ozone. This is thought to be aided by the denitrifications reactions that also occur on the surface of the PSCs and remove the nitrogen that could have lead to the reformation of less-reactive chlorine compounds.

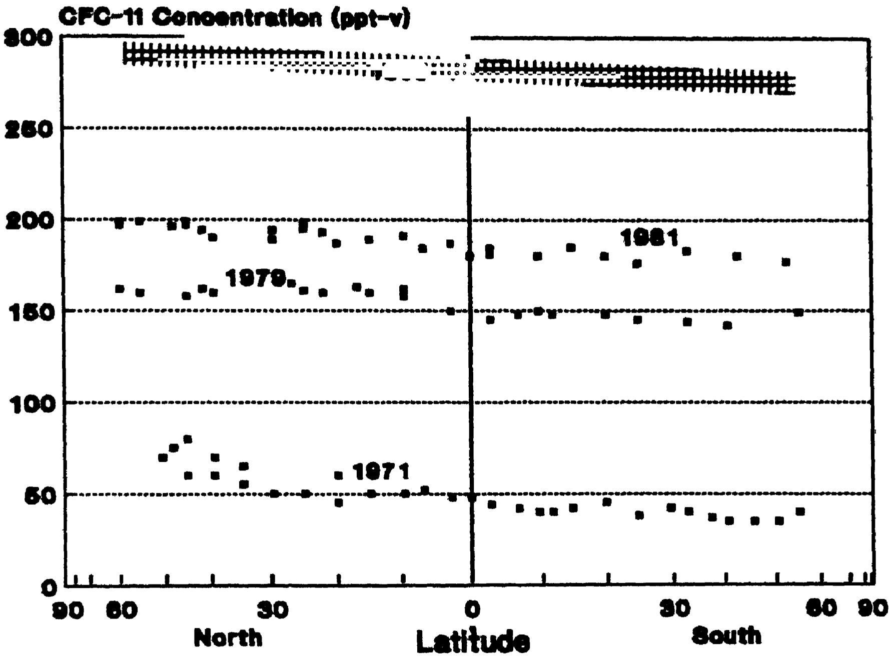
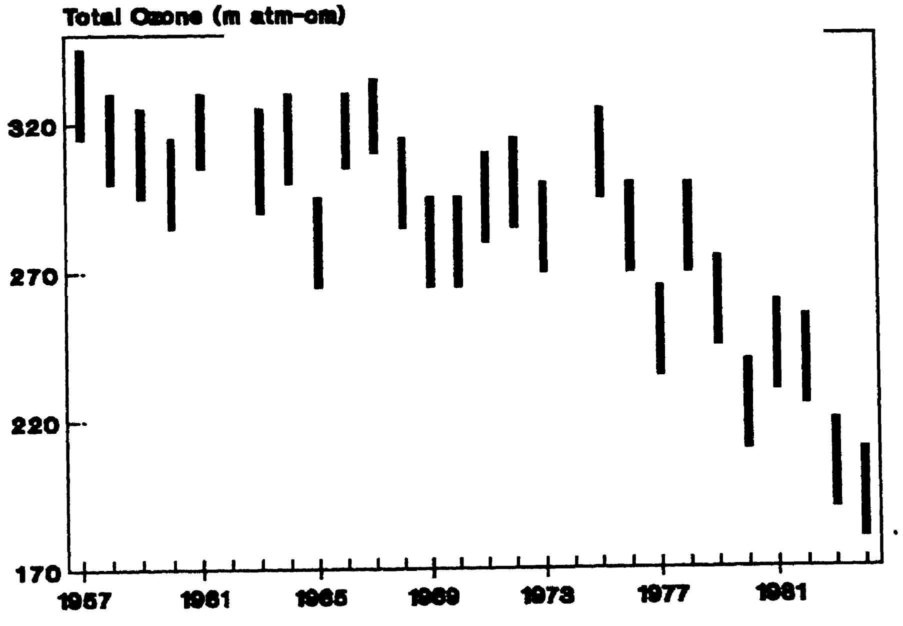


Figure 1: Concentration of CFC-11 in surface air samples collected at various latitudes.



Source: Farman et al. (1985)

Figure 2: Monthly means of total Ozone measured at Halley Bay, Antarctica, for each October from 1957 to 1984.

As a result of ozone depletion, the UV ray intensity at the surface of the earth increases. Figure 3 shows the existing levels of UV radiation at different latitudes, as well as the expected increase due to a decrease in the total ozone at different latitudes (Ilyas, 1989). The percentage increase is much higher at the higher latitudes than at the lower latitudes for equivalent ozone depletion. However, with ozone depletion preferentially occurring in the higher latitudes, the changes are expected to be far greater there than in the tropics since the absolute levels of UV radiation, even after substantial increases, in the higher latitudes will be less than in the tropics. No changes in the ozone or UV radiation over India have been noted as yet (Mani, 1991).

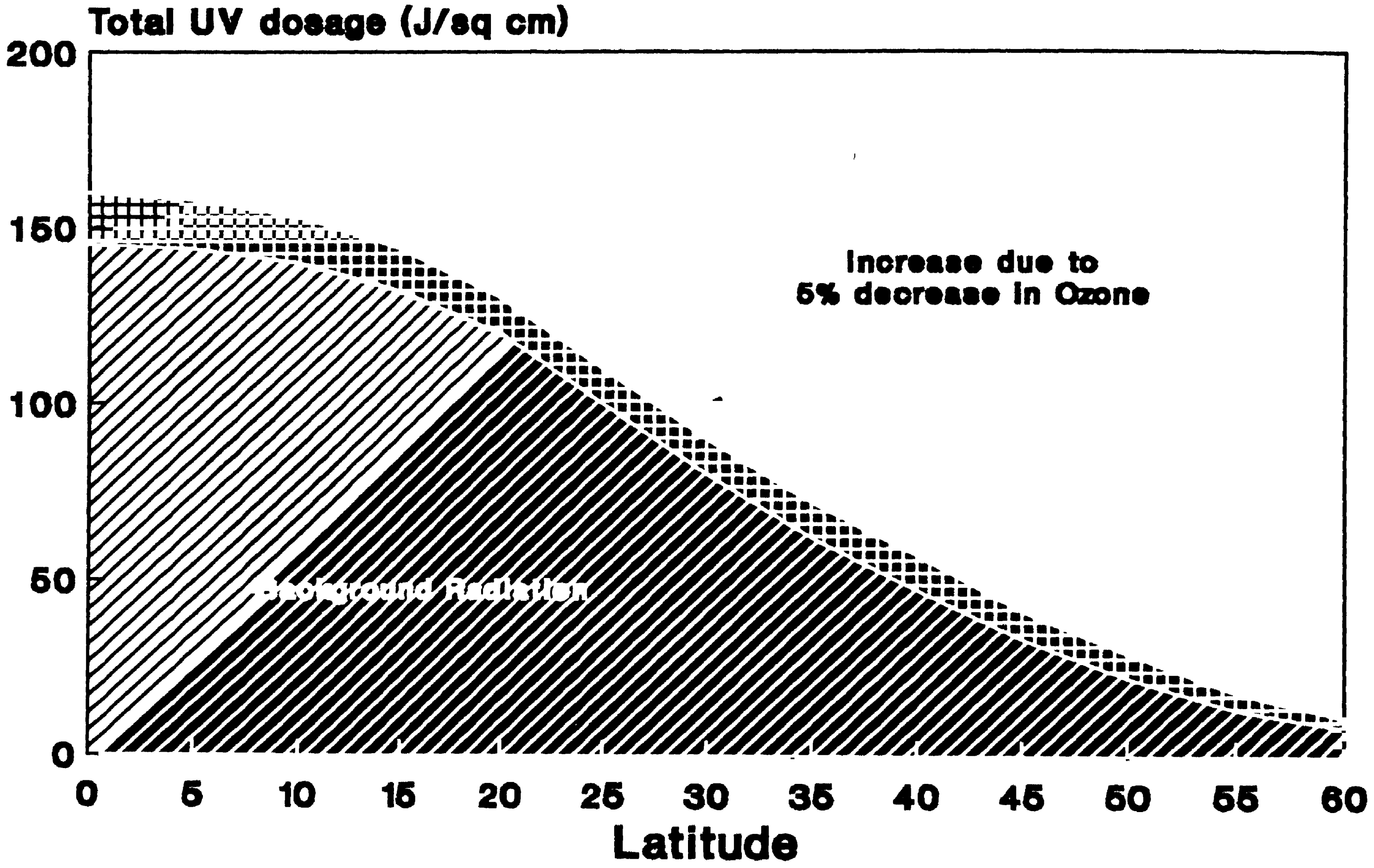


Figure 3: Background UV radiation and estimated increase due to 5% Ozone depletion.

The impacts of enhanced UV radiation on earth*

The decrease of ozone molecules in the stratosphere implies that less UV radiation is absorbed by them (reaction (3) in box 1), and consequently more of it reaches the earths' surface. One particular component of the UV radiation, UV-B radiation is of particular importance. With ozone layer depletion, UV-B radiation reaching the ground increases, and its average wavelength shortens. Most effects of UV radiation depend strongly on the wavelength, with the largest impacts associated with the shorter wavelengths. At the wavelengths that UV-B reaches the earths' surface, it has a multitude of effects on humans, animals, plants, and materials. The quantitative nature of many of these impacts is not certain, and is the subject of research presently.

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* This section is based on the UNEP Effects Panel Report (1989)

Human health

In humans, exposure to increased UV-B radiation can lead to suppression of the bodys' immune system which leads to an increase in the occurrence or severity of infections diseases, and a possible decrease in the effectiveness of vaccination programs.

Enhanced levels of UV-B radiation can lead to increased damage to the eyes, particularly cataracts which are estimated to increase by 0.6% for 1% total ozone depletion. Therefore, in the coming decades, each 1% ozone depletion is predicted to lead to a worldwide increase of 100,000 blind persons due to UV-B induced cataracts.

The other major expected impact on humans is an increase in the incidence of non-melanoma skin cancer. The percentage increase will be much faster than one-to-one: it is expected that every 1% ozone depletion will lead to a 3% rise in the incidence of non-melanoma skin cancel.

Plants

About half of the plant species investigated are found to be sensitive to UV-B radiation, the impact typically leading to reduced growth and smaller leaves. In some cases, these plants also show changes in their chemical composition which affects the quality and availability of mineral nutrients. In certain economically important food species (e.g. soyabeans), increased UV-B radiation corresponding to 25% decrease in total ozone results in a 25% reduction in food yield.

Aquatic ecosystems

Increased UV-B irradiance has been shown to have a negative influence on aquatic organisms, particularly small ones such as phytoplankton, zooplankton, larval crabs and shrimp, juvenile fish, etc. Most of these small organisms are at the base of the marine and global food chain, and increased UV radiation could result in major impact on fisheries productivity.

These are indications that increased UV-B radiation also lead to a decrease in the nitrogen assimilation through prokaryotic micro organisms, and thereby cause possible nitrogen deficiency in rice fields.

Materials damage

Exposure to UV radiation is a significant cause of degradation of many materials, especially plastics. This degradation is found to be enhanced by high temperatures and bright sunshine.

The Politics of the Montreal Protocol

In response to the initial scientific concerns published in 1974 linking CFCs to ozone depletion, some nations quickly banned the use of CFCs as aerosol propellants. This initial phase of regulation, however, led down a blind alley. Only a handful of nations imposed limits on the use of CFCs as aerosol propellants, with the majority adopting a "wait-and-see" attitude. Furthermore, the national regulations that were adopted affected only aerosols and therefore did little to encourage innovation regarding other uses of CFCs. In fact, CFC use increased in the refrigeration, foam and electronics industries throughout this period: because the aerosol ban was mistakenly thought to have solved the problem of ozone depletion, industry shelved its plans to develop CFC substitutes. By 1985, CFC use in the United States had reattained the previous levels reached in the mid-1970s.

The independent national regulations also led to a contentious debate in the mid-1980s regarding a possible international approach to limiting CFCs. With some countries already having taken action while others had not, the early negotiations failed to find a common point of departure. Further actions to limit CFCs on a use-specific basis proved especially problematic. Who was to decide which uses of CFCs were essential - high quality perfume in Paris, or automobile air conditioners in Washington, DC?

Several years of difficult negotiations made it clear that limits on specific uses of CFCs would not provide a workable basis for an international agreement. Only through the concept of production cutbacks, combined with the increased scientific consensus regarding the causes and effects of stratospheric ozone depletion, was progress around the negotiating table possible. Even then, the resulting 1985 Vienna Convention on the protection of the Ozone Layer was only a framework agreement that by itself would do little to prevent further ozone depletion.

By the mid-eighties, scientific studies had concluded that increasing emissions of CFCs would irreparably damage the ozone layer. In 1985, there was a starting announcement of a substantial loss of stratospheric ozone over Antarctica (Farman et al, 1985). This loss occurred during the Austral spring and had been noted every year since 1977 (Figure 2).

Consequently in September 1987, a number of countries met in Montreal, Canada, to sign the Montreal Protocol on Substances that Deplete the Ozone Layer. The Protocol did not take effect immediately, however, because at least 11 countries representing at least two-thirds of world consumption were required to ratify. Towards the end of 1988, a sufficient number of countries had signed the Vienna Convention and the Montreal Protocol to allow it to come into force.

The early years of the protocol

Unlike previous national limits on the uses of ozone-depleting chemicals, the Montreal Protocol dealt directly with the production of these chemicals. This agreement required nations who join to restrict their production and import of eight primary ozone-depleting chemicals. As it was originally formulated, the Protocol froze production and consumption of five CFCs at 1986 levels by 1989, reduced them to 80% of 1986 levels by 1993, and to 50% of those levels by 1998. Production and consumption of three halons was to be frozen at 1986 levels by 1992.

By limiting CFCs at their point of production, the Montreal Protocol ensured a reduction in the amount of pollutants generated. In doing so, it also avoided the problems of selecting individual uses to control, of establishing emission limits for each use, and of monitoring and enforcing across all uses.

Several countries soon adopted measures to further reduce the use of CFCs. In June 1988, the Swedish Parliament passed legislation that included specific deadlines for the complete phase-out of CFCs in new products, with consumption halved by 1991 and virtually eliminated by 1995. Austria announced its plan to reduce its consumption of CFCs by 50% in 1991. Australia proposed a 95% reduction of CFC use by 1995 and a full phase-out by 1998, and Norway introduced a broad initiative that, with some exceptions, eliminated all consumption of CFCs by 1991.

While some use-specific restrictions have been implemented on a national basis by many of these countries, these actions have been taken within the framework of an international agreement that deals specifically with the production and consumption limits.

Voluntary agreements with user-industries also played a significant role in several nation's strategies to reduce the use of CFCs and halons. In several countries, including Finland, Mexico and Egypt, use reductions were supported by voluntary agreements with specific user industries. The European Community negotiated voluntary agreements with the refrigeration and foam sectors. In West Germany and the Netherlands, industry voluntarily agreed to phase-out CFCs as much as possible by 1995. In the United States, the food-pack aging industry has virtually eliminated CFC use in manufacturing foam products by shifting to alternative blowing agents, and the fire-protection industry has announced voluntary reductions in halon emissions during testing procedures and other unnecessary uses of halons.

Recycling is another pollution prevention strategy that became a priority among many nations seeking to reduce CFC emissions. Austria and Norway proposed requirements to recycle or recapture and destroy all CFCs used in refrigerators and air conditioners when serviced or discarded. Local governments in West Australia and some Canadian provinces controlled emissions through recycling in their jurisdiction. Several states in the US passed laws governing recycling and recapture of CFCs, and the EPA has developed a national recycling programme.

An excise tax passed by the U.S. Congress on the sale of ozone-depleting chemicals in 1989 also aided CFC recycling in the US by increasing the costs of virgin controlled substances. As CFCs become more scarce, the incentive for both producers and users to recycle has increased. Because of the higher cost of virgin CFCs, both due to scarcity and because of the excise tax, the payback period for capital invested in recycling equipment was reduced. Furthermore, the excise tax exempted the resale of chemicals that are recycled. Recycling the controlled substances, instead of buying virgin chemicals, lowered the costs of doing business for users.

The tax on ozone-depleting substances also created a market for substitute chemicals. Because substitutes cost more than CFCs, no market for these alternatives could exist without higher CFC costs. The tax, in addition to the limited supply of CFCs, increased the cost to users and thus sent the needed signal to the marketplace to shift to alternatives.

The developing countries and the montreal protocol

During the discussions leading to the formulation of the Montreal Protocol, several developing countries made the point that the use of CFCs and halons was ultimately connected with development. Their use in many modern services and amenities, such as aerosol sprays, foam insulation and cushioning, cleaning of computer chips, and especially in refrigeration and air-conditioning, makes then an essential component of the industrialization occurring in the developing countries. In many of these countries, large investments had been made in projects based on CFC utilization, and the developing countries could ill afford the early retirement of these facilities in order to adhere to the processes of the Protocol.

Consequently, the Protocol created a special exemption for the developing countries. It provided a 10-year lag in Protocol implementation for countries whose per capita consumption is less than 0.3 kg per year. These countries, called

Article 5 countries (after the article that specifies this exemption), were also promised all practicable help in ensuring access to technology for substitutes.

At this point, the major developing countries that were not party to the Protocol were India and China. Both these countries largely ignored the Montreal Protocol formulation process as they were relatively minor users of CFCs (in the late eighties, they together accounted for about 5% of world consumption; Shea, 1989).

However, both countries soon had to take note of the Protocol. There were two reasons for this. The first was that the Protocol imposed strong restrictions on the import and export of CFCs and of products using CFCs. The trade of these compounds with non-Parties was banned within a year of the Protocol's entry into force. The Protocol also contained a provision for the consideration of banning trade of CFC-containing products with non-Party countries. This occurred at a time when the exports of both CFCs and of refrigerators from India were just picking up. The Protocol seemed to be a closing gate to the India CFC and refrigerator exporters.

The second reason was that both India and China became the focus of attention for the international community. The large size of these countries, their self-sufficiency in CFC-production, and their rapid growth rates indicated a potential for the skyrocketing of global CFC use. It was felt that, "if India and China achieve their modernization and electrification goals for the next decade, all CFC abatement efforts by the industrialized countries would be nullified" (Rosencranz and Milligan, 1990).

In the perspective of the international pressure, and the growing scientific evidence of the increases in ozone destruction, the Government of India took cognizance of the issue in 1988. At a meeting in the Ministry of Environment in that year (at which this author was present), the scientific ministries urged Indian ratification of the Protocol. The Ministry of Industry (which had just prepared its assessment; Government of India, 1988) pointed out that CFC/halon substitutes would be four to five times as expensive as the ozone-depleting substances that they would replace. The argument was ultimately tilted in favour of the costs-proponents through the issue of domestic refrigerators. The refrigerator, which was shedding its image as a luxury good, was now penetrating new markets amongst the lower middle-class and the rural population. The second-hand market was also thriving, and personal anecdotes of 20-year life of refrigerators (with one or two recharges) abounded. The Government decided that it could not penalize refrigerator owners (for many of whom this purchase was the largest single investment ever made by them) by denying the CFC-recharge and thus forcing them to buy a new (non-CFC) refrigerator.

Later that year, at the UNEP Ministerial Meeting on the Montreal Protocol in Helsinki, the Minister for Environment stated, "The developing countries muster the resources necessary to meet the minimum needs of their citizens at great sacrifice. These countries will be unable to spare further resources for the substitutes to CFCs. The poor of the developing countries will look askance at a government that spends resources on substitutes to CFCs to prevent depletion of the ozone layer.....while they continue to wallow in poverty, hunger, disease and ignorance.

The Government as an observer to the Bureau of Parties to the Montreal Protocol, initiated an amendment to the Protocol that would provide for international funding to meet the costs of implementing the Protocol in the Article 5 countries. The Government also agreed to a British offer of carrying out a study to assess the costs of Protocol implementation in India. By 1990, Mrs. Maneka Gandhi, who had become Environment Minister, urged halting of domestic production of CFCs, and demanded that substitute technology be made available at no, or low cost. She also insisted that foreign companies provide free CFC-alternative patent rights to the developing countries that need them.

The first reaction of the industrialized countries was to view the demand for international funding as blackmail (see, for example, Moritz, 1989). The developing countries, led by India and China, took the high moral ground and invoked the, "polluter pays principle"; pointing out that since the vast majority of CFC emissions had occurred from the industrialized countries, the costs incurred by the developing countries in phasing out their use should be borne by the former. This point of view was quickly accepted in principle by most industrialized countries, but commitment to provide the funds for meeting the costs related to the Protocol implementation were less forthcoming.

In 1990, new scientific assessments relating CFC emissions to projected ozone depletion were published. These indicated that severe depletion of the ozone layer could be expected even if the CFC consumption limits laid down in Protocol were observed (see, for example, Bruhl and Crutzen, 1990). These studies reinforced the need for adjustments for the CFC consumption limitations so as to minimize ozone depletion. It also highlighted the need to ensure that major developing countries like India and China joined the Protocol.

In the perspective of the scientific findings, and the strong stand taken by India and China, the Parties to the Protocol agreed to amendments that would allow the developing countries to be compensated for costs associated with Protocol implementation. An ad-hoc financial mechanism called the Interim Multilateral Fund, was established at the June, 1990 meeting in London with a core funding of US$ 160 million to go up to US$ 240 million and US$ 320 million as China and India joined the Protocol. The Fund was to be financed by payments from the industrialized countries; each country's contribution calculated in accordance with its UN assessments.

At the London meeting, the CFC phaseout limits were also considerably tightened in response to the findings of the scientific assessments. The industrialized countries were required to completely phaseout most ozone depleting substances by the year 2000. In addition, Carbontetrachloride and methyl chloride were added to the list of the controlled substances.

After the June 1990 meeting there was again considerable international pressure on India and China to immediately join the Vienna Convention and the Montreal Protocol. In 1991, China signed the Protocol. India steadfastly refused to sign until the London amendments came into force after ratification by an adequate number of Parties. Soon after this occurred, India signed the Vienna Convention in March 1992, and then the Montreal Protocol in June 1992. Following a statutory three-month waiting period, India become a Party to the Montreal Protocol in September 1992. In the 4th meeting of the Parties held in Copenhagen in November 1992, the Indian Minister for Environment and Forests, Mr. Kamal Nath was elected President of the Bureau of the Parties to the Montreal Protocol.

Implementing the Montreal Protocol in India

The ad-hoc financial mechanisms of the Protocol was granted statutory approval at the Copenhagen meeting in November 1992, and Multilateral Fund of the Protocol came into existence from 1st January 1993. The Fund is managed by 14 member Executive Committee established by the Parties, which has a balanced representation of Parties which belong to the industrialized countries and those belonging to Article 5 countries. The Executive Committee meets thrice a year to consider and approve requests for funding submitted to it. The committee is assisted by the Fund Secretariat based in Montreal. Projects and activities are undertaken through four international organizations which are designated as Implementing Agencies. These are UNDP (United Nations Development Programme, the World Bank, UNEP (United Nations Environment Programme), and UNIDO (United Nations Industrial Development Organization). These implementing agencies develop projects in collaboration with the countries, present them for approval to the Fund, and then supervise the project implementation.

The contribution to the Multilateral Fund have been fixed at $ 113 million for 1993. The level of funding for the 3-year period from 1994 to 1996 will be in the range of $ 340 to 500 million; the exact quantum is to be decided at the next meeting of the Parties in November this year.

In order to assess their funding requirements, in the perspective of their national strategy for the implementation of the Montreal Protocol, all Article 5 countries are required to prepare Country Programmes. These Country Programmes look at the current structure of the ODS user and producer sectors, their anticipated growth rates, define the phaseout strategy in the various users sectors, assess and evaluate technical options for phaseout, and assess the cost of phaseout.

After India became a Party to the Montreal Protocol, the process of Country Programme preparation and identification of projects for funding commenced. The Ministry of Environment and Forests chose UNDP as the Implementing Agency for Country Programme preparation. Broadly, it was agreed that World Bank would the Implementing Agency for large investment projects, the UNDP for smaller investment projects, UNIDO for projects in the small scale sector and UNEP for projects related information dissemination and awareness. An Ozone Cell was created within the Ministry of Environment and Forests to be the nodal agency for Montreal Protocol implementation.

In March this year, the Ministry of Environment and Forests and UNDP identified the Tata Energy Research Institute to be the lead agency for the preparation of the Country Programme. Throughout the process of Country Programme formulation, there has been a continued emphasis on close government-industry interaction. There has been a conscious effort to involve industry as an equal partner in formulating the programme so that they have a stake in the implementation of the programme as well. The first government-industry meeting was held in New Delhi in January this year. Following this, there were several workshops related to project preparation for examining the technical options and strategies for phaseout in various users sectors (i.e. Refrigeration and Air Conditioning, Foams, Aerosols, Solvents and Fire Fighting). Sectoral groups, consisting of industry representatives were formed in June 1993 to draft sectoral recommendations for the Country Programme. They were assisted by international experts provided by UNDP. These drafts were prepared and presented at a national workshop on the Country Programme in July this year. These were then assessed and integrated in the perspective of the national phaseout strategy.

Figures 4 shows the expected growth of ODS use in various sectors till 2010. The Montreal Protocol requires phaseout of various groups of ODS according to specified time tables. The limits imposed by the Montreal Protocol and the phaseout profiles for the four groups of ODS used in India are shown in Figures 5 to 8. In arriving at these phaseout profiles, various technical options were examined. In the Aerosols sector, the strategy is to move from CFC to LPG. In the Refrigeration sector, the preferred strategy is presently seems to be move to a completely fluorinated fluorocarbon (or, Halogenated Fluorocarbon) HFC-134a. In the Foams sector, the strategies are not very clear as yet; there is some move towards hydrocarbons, and new HFCs may be preferred in certain options. In the Solvents sector, the move is largely towards water based systems. In certain pharmaceutical solvents applications, the use of CFCs will continue, and is allowed under the provisions of the Protocol. In the Fire Fighting sector, Halons will have to be completely phased out. There are plans to build up a bank of Halons so as to provide a buffer stock till substitutes become available. In this sector, the Protocol allows retaining some halon use for essential purposes.

A major finding that emerged during the process of Country Programme preparation was about two-thirds of CFC used in India occurred in the small scale and informal sectors. During the process, large units using CFCs, as well as larger small scale industries were identified, and included in the programme. However, based on data on supply patterns provided by the CFC producers, it was apparent that large quantities of CFC use had not been included. These were assumed to occur in small scale and informal sectors. We currently estimate that the unidentified small and tiny units accounts for 26% of ODS consumption in the refrigeration and air conditioning sector; 45% in the Aerosols sector; 40% in the Solvents sector; and 6.7% in the Fire Fighting sector. The unit cost of phaseout in the small and tiny units have, at present been estimated to be 250% of that in the larger (identified) units.

There was also concern about the CFC based refrigerators that would still be in service after 2010, and may need a CFC recharge. It was decided that the Country Programme would approach this problem through three options. It would provide an incentive for trading in these refrigerators; it would establish a CFC recycling programme; and it would help in retrofitting CFC refrigerators so that they could be charged with non-CFC refrigerants.

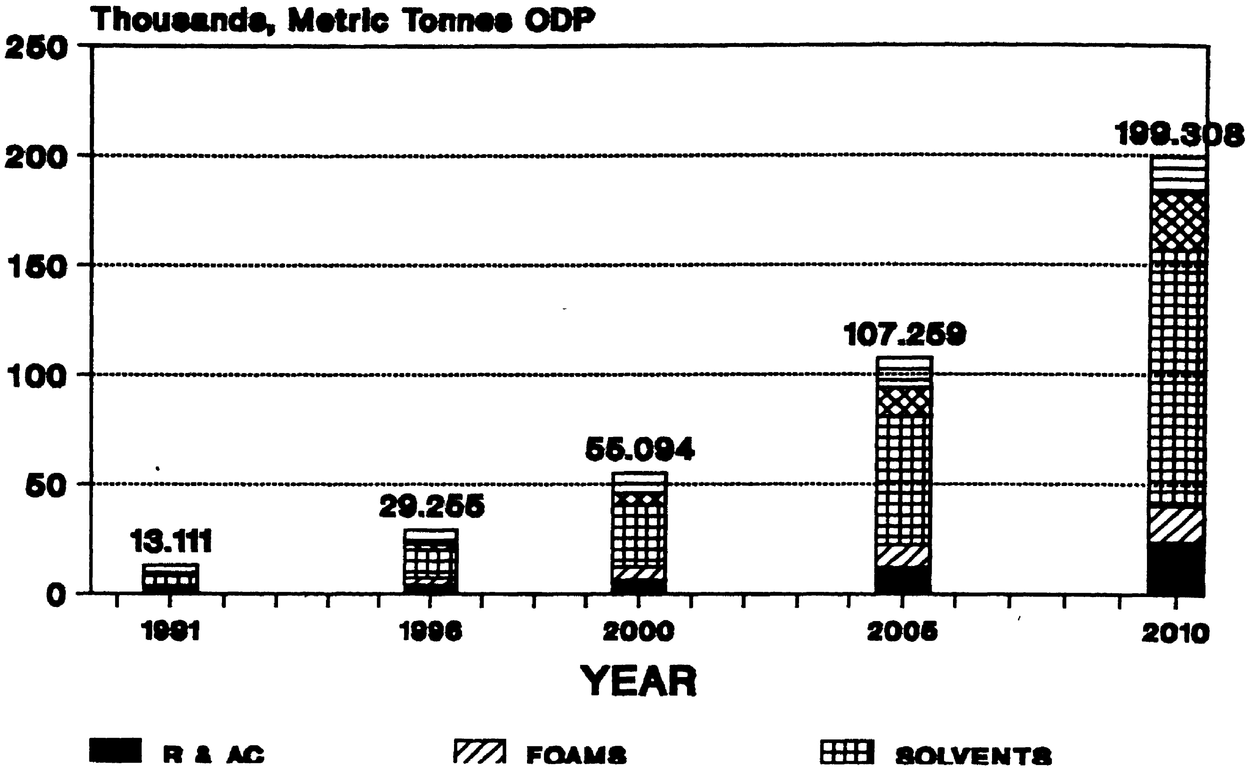
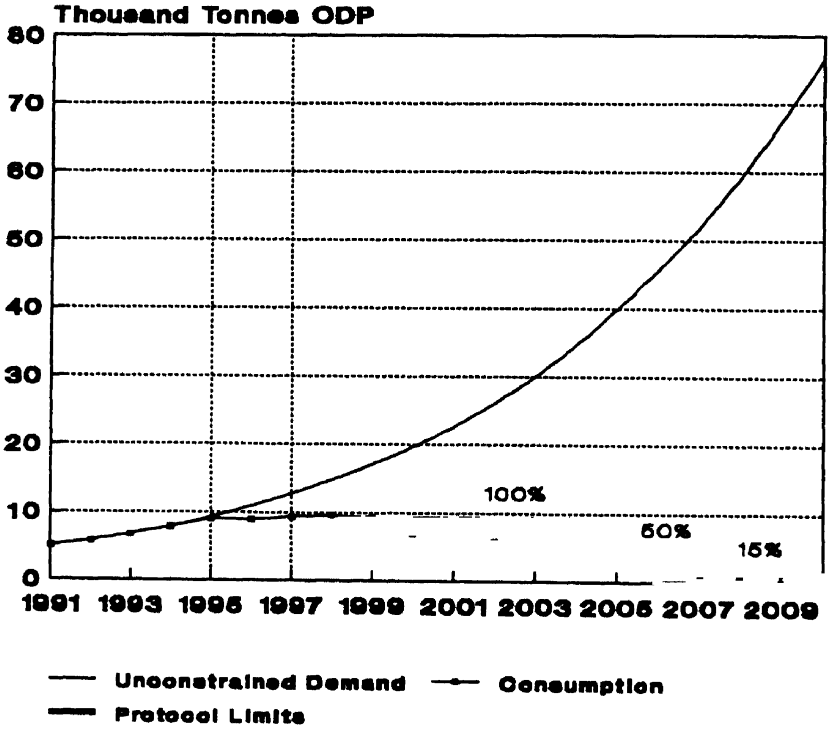
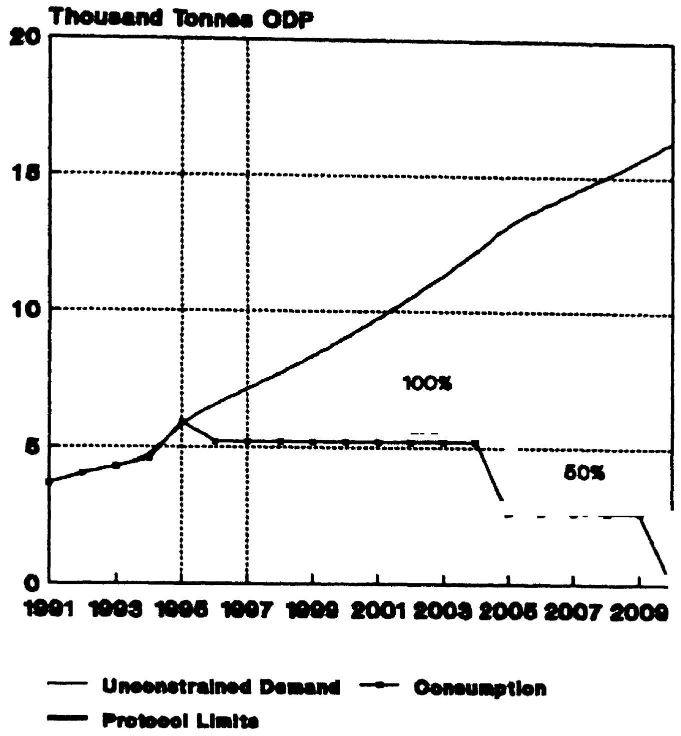


Figure 4: Estimated unconstrained ODP demand by sector to the year 2010.



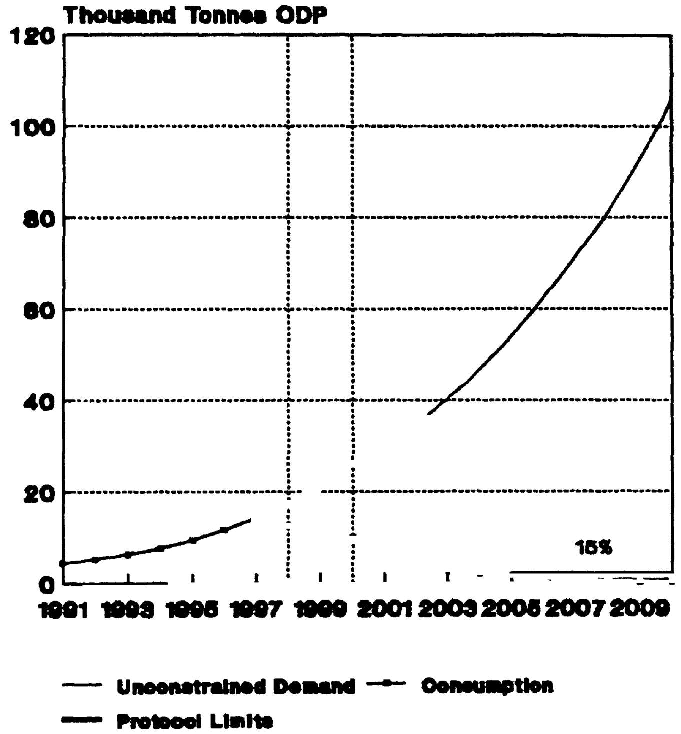
Protocol limit percentages are based on average consumption in the years 1995 to 1997

Figure 5: Phaseout of Annex A Group I ODS (CFC-11, CFC-12 and CFC-113) in India.



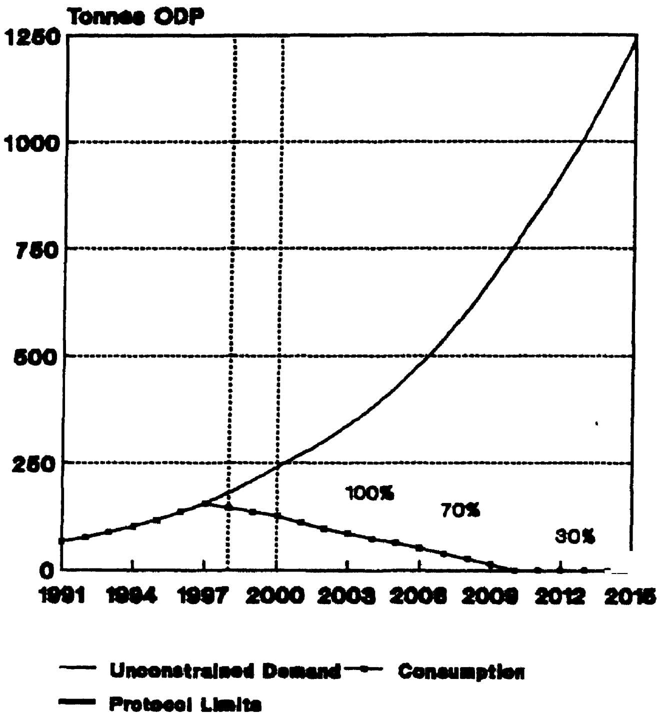
Protocol limit percentages are based on average consumption in the years 1995 to 1997

Figure 6: Phaseout of Annex A Group II ODS (Halon-1211 and Halon-1301) in India.



Protocol limit percentages are based on average consumption in the years 1998 to 2000

Figure 7: Phaseout of Annex B Group II ODS (CTC) in India.



Protocol limit percentages are based on average consumption in the years 1998 to 2000

Figure 8: Phaseout of Annex B Group III ODS (MCF) in India.

The one other major problem faced by India is the issue of the availability of CFC substitutes. India is one of the five Article 5 countries that has indigenous production of CFCs. In fact, over the last 5 years, India has been exporting CFCs to various developing countries. The CFC manufacturers have also installed large plants in view of their rapidly increasing consumption. The Country Programme seeks to compensate the CFC producers for their lost capacity, as well as to help them to establish new facilities for the production of CFC substances in the country.

The integrated Country Programme was presented at the second national workshop in August. It was subsequently approved by an inter-ministerial group, and then by the Union Cabinet on September 5, 1993. The net incremental costs of phaseout are presented in Table 1.

The Country Programme was approved at the 11th meeting of the Executive Committee of the Multilateral Fund in November 1993. The Executive Committee, in keeping with prior practice, approved the Country Programme without approving the indicated costs.

The Government of India requires the Implementing Agencies to use the IDBI and the SIDBI as the local financial institution to manage the projects funded by the Multilateral Fund. The institutional agreements between IDBI and the World Bank and UNDP are currently being finalized. The IDBI will be initiating project preparation activities from September 1994.

Enterprises prepare proposals in collaboration with Implementing Agencies/IDBI, and submit these project proposals to the Ozone Cell in the Ministry of Environment and Forests. The projects are reviewed by a standing technology and Finance Committee that consists of independent experts, as well as representatives of IDBI, Engineers India Limited, etc. Clearance for forwarding proposals to the Implementing Agencies is provided by an Inter Ministerial Committee. The Agencies, typically, conduct independent reviews before submitting the proposal to the Fund. After approval by the Executive Committee of the Fund, the Fund Secretariat transfers the approved grant to the Implementing Agency, which in turn will transfer the monies to IDBI.

In the past year and a half, about 125 candidate enterprises have been identified, and projects for over 50 enterprises have been prepared for project funding. Twenty eight proposals have been forwarded by the Government of India to the Implementing Agencies; and sixteen have been approved by the Fund for a total grant of $8.43 million. These projects are in the Aerosol filler sector, Foam blowing sector, and the refrigeration sector. No approved grants have yet been disbursed because the agreements with IDBI are yet to be finalized. In addition, an Indo-German bilateral project on substituting CFC-12 by hydrocarbons in domestic refrigerators is also underway.

Important Issues

The process of CP preparation was a unique and rewarding experience as it was for the first time that the industry and Government worked together in a cordial atmosphere to plan their strategies for an international cause. The Montreal Protocol is the first international agreement ever made to protect the global environment. The success of the Montreal Protocol Implementation in India would depend on both the Government and the ODS user industry. The commitment on the part of the Government of India to adhere to the provisions of the Montreal Protocol is directly linked to the efforts put in by the ODS users for reducing the consumption of these chemicals at their plants. That such a cooperation will be forthcoming was evident because a number of important issues which came up during the meetings were discussed and mutually resolved. Many of the issues still remain unresolved but it can be expected that with a concerted effort and willingness on the part of the Government and the industry, the transition into an ODS free environment would be a smooth process. Some of the important issues which need a mention here are given in the following paragraphs.

One of the important and fundamental issues which was discussed at length was the base year ODS consumption in the country and other related aspects like the unconstrained growth expected in the industry.

The base year suggested by UNDP was 1991. It was felt that it would be fallacious to use 1991 as the base year since that was an year of recession for the Indian industry especially in the refrigeration and airconditioning sectors.

However, it was mutually argued and agreed that since the Executive Committee of the Multilateral Fund expects the most recent data, 1991 data can be provided and growth rates taken accordingly to correspond to the actual growth occurred in a particular industrial segment. The ODS consumption for 1991 was calculated based upon

i) the indigenous production of various ODSs and their sectorwise consumption;

ii) the imports and exports during 1991.

Since the basis of this data was only the producers estimates of ODS consumption in the five end-use sectors viz. Refrigeration & Airconditioning, Foams, Aerosols, Halons and Solvents, it was felt that a user survey of ODS consumption would be beneficial to confirm the actual consumption in each sector. This would form a basis for the monitoring of the consumption levels in various industries for the purpose of reporting to UNEP and help in the implementation of the Montreal Protocol phasedown schedules as envisaged in the India Country Programme document. It was also felt that such an exercise would help identify the presumably large usage in the tiny and unorganised sector, where the annual consumption levels are of the order of 1-2 tonnes or even less. The information gathered by Government from this user survey would be used in the first India Country Programme update scheduled for 1995.

The country programme preparation process requires the country to estimate its ODS consumption levels in future (upto 2010) assuming there had been no restrictions under the Montreal Protocol. These unconstrained growth estimates are very important since it would help both the country and the MP Executive committee to know the effort which is required to be put in to keep the ODS consumption within the MP limits. The UNDP experts were of the view that it is difficult to explain high growth rates assumed by the industry over a long period and in case the industry and the Govt of India is sure about it, these estimates must be substantiated with logical reasoning. The Government and Industry felt that the recent measures being undertaken by the Govt. for the liberalisation of the Indian economy are expected to lead to a more dynamic and competitive industry, and to a burgeoning demand for consumers goods, particularly in areas like refrigerators and air conditioners, aerosols, electronics devices, light engineering goods etc. The increase in the demand will be further stepped up due to certain other factors like increasing per capita incomes, increasing availability of consumer credits and most importantly the Govt. of India's thrust on rural electrification. Govt. of India has recently taken a series of dynamic measures to impart a new dimension to the economic fabric of the country. The reduction in excise duties on a number of industrial products has tended to promote growth in the industrial sector. As rupee has been made convertible, exporters have found it easier to build up their business. The New Industrial Policy has helped carry forward the impact of liberalisation, deregulation and technological advancement. The market has been opened up to Foreign investments and it is now increasingly being accepted by the potential foreign investor that India is one of the best bets for business investment in future. 100% foreign equity with free benefits of repatriation of capital and income to NRI's and overseas corporate bodies has attracted large scale NRI investment. All these reforms are expected to lead to tremendous growth opportunities in industrial segments and since the ODS usage pervades almost all segments of the Indian economy, in general the unconstrained growth rates in ODS consumption will also be correspondingly higher.

Regarding the phaseout, Govt of India was initially inclined to have a delayed phaseout plan because it was felt that the alternative phaseout strategies were still unclear and this would give the country a greater flexibility in planning its options for ODS phaseout. However, in contrast, some of the ODS users were of the view that it would be possible for them to phaseout early. The matter was discussed at length during the Second National CP Workshop and the phaseout schedules were advanced for foams and aerosols. As a result, the phaseout starts early in these two sectors while it extends till 2010 in cases like domestic refrigeration and the small user segments in the solvents sector. Several ODS users who are exporting their goods to European and other non-Article 5 countries would have to meet the deadline of 1 January 1996 which has been set for the developed countries. This aspect was mutually discussed by the Govt with the industry and was duly taken care of while deciding the phaseout plans of the various sectors. In addition, the Aerosol industry felt that there was a cost advantage associated with the changeover and hence their desire for an early phaseout was also met. Infact aerosols in the only sector which would completely phaseout its ODS consumption by 1998.

The incremental costs for ODS phaseout in the country were also looked upon by the various sectoral groups. In this particular case, the experience of the international experts who had worked on similar country programmes in other developing countries was found to be very helpful. The view of the Govt. of India that the phaseout costs in SSI and informal Sector would be atleast 2.5 times the unit phaseout costs in larger industries was accepted by the industry. Out of the total incremental phaseout cost for the India CP of US $1964 million, the Small Scale ~~and~~ Informal Sector accounts for US $390 million. The Government of India's concern for the Indian industry is evident from the principles which it has adopted for the choice of projects to be approved for finding. These principles in short are:-

1. **Minimize economic dislocation**: The process should not lead to closure of units, loss of productive capacity, or major capital expenditure for modifying facilities (such as existing equipment for production, transport and storage) which could become obsolete. In determining economic feasibility, energy efficiency and machine characteristics will be considered.

2. **Maximize indigenous production**: Transfer of technology and local production of substitutes and equipment will be encouraged. This will require good test methods and facilities.

3. **Preference to one time replacement**: This will be preferred unless there is another more cost-effective alternative; and for which information will be required on the availability and assessment of substitutes.

4. **Decentralized management**: Development of arrangements to facilitate feedback for smooth implementation; including awareness building, training and consumer protection. For efficient ODS phaseout, particularly in the small scale and informal sector, the feasibility of implementation has to be studied and planned.

5. **Development of standards and certification system**: New standards (including those for safety) are needed for production and distribution operations.

6. **Minimize obsolescence costs:** Existing technology would be kept running as long as possible by recycling and using drop-in substitutes while new technologies are phased in as they become available. This will minimize the cost of obsolescence.

However, there are some issues which still remain unresolved even after a lot of discussion among the participants. One of the major issues was the desire of the industry that the taxes and duties which would form a major component of the ODS phaseout costs borne by the industry should be waived off. These costs are not covered by the Multilateral Fund as these are transfer payments between the Govt and the industry. The Govt. of India took note of the Industries demand and promised to look at it positively. There was also an apprehension expressed by a section of the industry that the procedure adopted by the Govt for the clearance of the projects for submission to the Multilateral Fund would lead to unnecessary delays. The MOEF tried to dispel these fears by stating that to ensure timely decision, time bound schedules would be drawn up by the Ozone Cell for the various committees/ agencies involved in the clearance of the project proposals.

Conclusions

The national and international processes that have occurred as a result of ~~the~~ finding that CFC emissions harm the ozone layer bring out five salient features. These are briefly discussed here.

The role of science in international agreements

The Rowland-Molina hypothesis and its subsequent confirmation sparked off various national initiatives to reduce CFC emissions. Subsequently, scientific evidence indicating increasing ozone depletion over a period of time served to highlight the urgency of the process. Undoubtedly, the threat of increased skin cancer due to enhanced UV radiation served to influence the decisions of many individuals to support the ban ~~on CFCs. The political~~ pressure of such individuals has been large enough in a large number of countries so as to enable the formulation of the Montreal Protocol.

The Protocol has also explicitly recognized the inputs provided by scientific observations, and the need to adjust international actions (for CFC limitation) so as to take new scientific data into account. As a result, adjustments are possible, and have been used to accelerate the CFC phaseout process in response to new scientific evidence. As a result of the last such assessment, the phaseout schedule in the industrialized countries has been advanced from the year 2000 (as agreed at London meeting) to the year 1996. However, at Copenhagen, the phaseout limit for the developing countries was not concurrently forwarded to 2006 (in the perspective of the ten year lag), but provisionally maintained at 2010. A decision whether the developing country phaseout limit should be brought forward to 2006 would be taken after the next assessment becomes available in 1995.

Table 1: Net incremental cost of ODS phaseout

Sector	Incremental costs ($ million)	ODP phaseout tonnes	Unit phaseout (US $/kg)
Aerosols	13	14366	0.90
Foams	150	14866	10.08
Fire Fighting	36	15208	2.37
Domestic refrigeration	295	5000	59.00
Other refrigeration and AC	120	11884	10.10
Solvents	104	69944	1.49
Trade-in of refrigerators and other appliances	325	200	1625
Recovery and recycling	50	2500	20
Chemical producers	466	-	-
Small scale and informal sector			
Other R&AC	105	4176	25.25
Foams (non-refrigerator)	84	1669	50.43
Aerosols (fillers only)	21	11754	1.75
Solvents	174	46629	3.73
Fire-fighting	6	1092	5.93
Sub total	390	65320	5.97
Administrative cost	15	-	-
Total	**1964**	**199308**	**9.85**

Note: 1. The above net incremental costs have been arrived at by computing the eligible costs on an annual basis upto the year 2010, at the 1993 value of US $.

The polluter-pays principle

The special consideration for developing countries that is built into the Protocol highlights the differentiated responsibility of the industrialized and developing countries in contributing to the ozone depletion problem. Though the Protocol states that the provision for the transfer of financial resources should not be considered as an international precedent, the weight of international public and moral opinion clearly recognizes this differentiated responsibility. It has now also been built into the Climate Change Convention.

It has also resulted in the concept of incremental costs in developing countries due to changes required because of international obligations. The evaluation of incremental costs, and the modalities for meeting these incremental costs are being presently established. The Multilateral Fund currently operates with a few, generic rules, and decides on issues on a case-by-case basis. During this process, the eligibility of various costs for being considered as incremental costs is tested, and international precedents established.

Government-industry interactions

For the first time in India, government and industry have worked to produce a common national document. For this reason, many have preferred to call a Country Programme as a national programme. It highlights the great potential for achieving clear goals in a timely manner when both the government and industry agree to undertake specific responsibilities. A major feature of the process is that it also engendered a close working relationship between companies that are fierce competitors in the market. The interactions revealed that industry is willing to make adjustments so as to realize national environmental goals.

Technology transfer

The Multilateral Fund process has spawned a new form of technology transfer. Individual companies in the industrialized and in the developing countries agree to technology transfer under the provisions of the Protocol. In the process of national and international project approval, the technology transfer arrangement is vetted for technological suitability as well as for economic efficiency. Consequently, it promotes the transfer of state-of-the-art technologies at internationally competitive prices. This is quite at variance with what was expected when the process started. It was felt at that time companies in the industrialized countries would charge large royalties for technology transfers.

This process has also forced a much closer interaction between industrial units across the world, and given rise to innovative forms of technology development. For example a US inventor is using an Indian company to develop the engineering plans and prototypes for a new (non-CFC) car air-conditioner for the US market.

Similarly, several European aerosol manufacturers are considering building filling plants in India. Leading-edge technology companies in areas such as refrigerator compressors are developing joint venture relationships with Indian companies.

Changing life styles

The Montreal Protocol process has demonstrated that people worldwide are willing to change lifestyles and incur personal costs so as to enhance environmental quality. This preference is also exhibited at the national level where the industrialized countries are willing to spend public money on amelioration of international environmental problems. For example the United States, which has been a chronic defaulter in paying its dues to UN organizations, is the only country to have met and exceeded its assessed dues to the Multilateral Fund.

The Protocol process has, above all, demonstrated the capability to, and the willingness of, countries to seriously negotiate potentially major economic transformations so as to achieve global environmental quality. It has, therefore, redefined the existing vested interests in international power-diplomacy, and opened the way for a new set of international bargaining aimed at environmental protection and sustainable development.

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SUSTAINABLE DEVELOPMENT: SOME INTERPRETATIONS AND APPLICATIONS IN THE CONTEXT OF INDIAN AGRICULTURE

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The problems of achieving sustainable development are explored in the context of Indian agriculture. The Green Revolution led to rising living standards, but unanticipated externalities caused a degradation of land resources. For non-green revolution areas, alternative sources of unsustainable development are identified. The inadequacy of standard analytical approaches to the issues of growth is considered, and the conclusion drawn that both ecological and social–political systems must evolve together to create an environment in which policies can successfully increase current living standards whilst protecting future production possibilities.

1. INTRODUCTION

The sustainability of development processes is essentially a consequence of the interaction between socio-economic and ecological systems. Socio-economic systems are faced with constraints or impulses originating from sources such as the carrying capacity, or the waste assimilating capacity of the eco-system. Thus what Norgaard (1981) refers to as a "co-evolutionary perspective" in viewing these inter-relationships becomes necessary.

Such a view is of particular significance within the context of agriculture, since this is an activity which uses the eco-system as a crucial input and alters it in the process. These alterations are caused by specific types of land use. The evolution of agricultural systems over time is the result of the interactive process between land use and the use of other resources such as livestock. Sustainability, therefore, implies consistency between socio-systems and eco-systems, interpreted as the long-run survival of specific types of land use. The concept of sustainability also implies seeing development as the consequences of such co-evolutionary interaction. This is a wider concept of sustainability than one concerned solely with optimal resource and environmental management.[2] This wider notion of sustainability has been linked to the presence of limits to growth. In the next section we review alternative analytical approaches to sustainability,

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[2] Barbier and Markandya (1990) make this distinction between a narrower and a wider interpretation of sustainable development.

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before going on to present an approach for operationalizing the concept and its implications for the prospects for Indian agriculture in the 1990s.

2. ALTERNATIVE ANALYTICAL APPROACHES

Classical political economy was concerned with the limits to growth. It maintained that unlimited growth was possible only in a utopia where there were no scarce factors. In reality 'land', or natural resources, are limited. Malthus was of the opinion that natural resources imposed an absolute limit, Ricardo concentrated on the relative scarcity of non-homogeneous resources. Perhaps J. S. Mill's concept of "a stationary state of capital and wealth", in which outputs and inputs grow at constant rates, represents the most balanced view in this debate. He hypothesized that the 'stationary state' may not be undesirable.[3] In this perspective we find a hint of an ethical approach to the economic problem, something that later scholars accuse economists of overlooking.[4] Mill notes that "there is room in the world . . . for a great increase in population, suppose the arts of life to go on improving and capital to increase" but "*very little reason to desire it*".

Two ideas are central to the above way of viewing growth. Firstly, although a limit may exist, it has never been reached as technological and organizational innovations push back the boundaries. Secondly, even if that final limit is not reached, it may not be desirable to maximize output. Following the technological changes brought about by the Industrial Revolution, economic theory tended to over-emphasize the former and ignore the latter. Marx did stress that "work is not the source of all wealth. Nature is just as much the source of use value as work, which is itself only an expression of a natural force, human labour power".[5] This seems to hint at the significance of nature as the possible limiting factor.

Neoclassical economics, as developed from the end of the last century, took the position that technological change could (and, in most cases, would) prevail over natural resource shortages. Although it was possible to introduce natural capital as another factor (along with man-made capital and labour) in the production function, the focus of growth theories was on the links between capital, labour, and technological change. Further, maximization of production was more or less accepted as a laudable principle. The new institutional economics supports this argument. It states that where prices cannot provide the right signals for resource allocation due to the fact that some commodities and resources remain outside the range of market-determined decision making, 'setting the property structure right' will work, i.e. a well developed system of property rights (private or public) is likely to solve many of the problems resulting from ecological constraints.

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[3] Malthus's "Essay on the Principle of Population" was first published in 1798, Ricardo's "Principles of Political Economy and Taxation" in 1817 and Mill's "Principles of Political Economy" in 1848. For one perceptive analysis of their views see Barnett and Morse (1963).

[4] See, for instance, Burgenmeier (1991) for a criticique of the artificial distinction made between the positive and normative aspects of economics. The criticique centres around the absence of an ethical underpinning in most of accepted economic theory.

[5] In reviewing the treatment of nature's contribution to production processes in economic thought, Seifert (1991), identifies Marx and the French physiocrats led by Quesnay as the significant proponents of the crucial significance of nature prior to the emergence of the new bio-economic paradigm.

Parallel to these developments in mainstream economic theory, ecologists stressed the inter-dependence between different natural processes, claiming that the processes involved were far more complex than the economist's monolithic concept of 'land' or natural resources would allow. All human activity constitutes disturbance of the original state of nature and nature's regenerative ability is not without limit. As Daly puts it, "the production process functions within the eco-system and its links with the eco-system should determine the optimal level at which it should function".[6] These ideas endorse the concept of upper limits to growth. However, economic theory remained somewhat estranged from such an holistic approach to the relations between human activity and natural processes.

An important link between economic theory and ecological perceptions can be found in the work of Georgeasu-Roegen. He maintains that production processes use up scarce 'available' or 'free' energy. In his words, "matter-energy enters the economic process in a state of low entropy and comes out of it in a state of high entropy".[7] This implies that low entropy resources are the source of scarcity.

Consequently, the limits to growth lie outside the economic system and in the second law of thermodynamics. The emerging field of bio-economics tries to put together the implications of such a paradigm for socio-economic processes. There seems to be a consensus that one such implication is that a complete recycling of resources is not possible and that an increase in entropy is an inevitable result of essential production. However, this in itself is not saying much. The true problem consists in the choice of the proper rate of increase in entropy,[8] so the levels of entropy associated with different production processes needs specification.

Optimal resource management models, strictly neoclassical in lineage, have embraced the concept of upper limits for degradation rates by studying the role of the environment as a sink which absorbs waste and pollution. Using control-theoretic methods, the permissible change in the rate of degradation can be calculated.[9] Such optimizing models result in a growth path which will not necessarily maximize output. More positively, the aim of some of these resource management models is to minimize both the damage inflicted on the environment and the costs of abatement, i.e. 'regret minimization' rather that 'output maximization'.

However, crucial differences between the resource management approach and the ecological thermodynamic approach remain. Most resource management models view the maintenance of environmental standards as a constraint to the maximization or minimization of discounted sums of utility or disutility streams, either over a finite or a infinite time horizon. Ecological approaches consider the preservation of resources to be of prime significance. The issue here is one of different approaches to the nature of the production process and the goals of economic activity. Does the production process use up 'valuable resources to produce valueless waste' as postulated by Georgescu-Roegen or does it produce utilities for the human population in the presence of limited resources, one of those being the absorption capacity of the environment?

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[6] See Daly (1990a) for a macro-economic interpretation of ecological phenomena.

[7] See *inter alia*, Georgescu-Roegen (1976), particularly chapter 3.

[8] For a similar approach to the problem, see Mayumi (1991). He also distinguishes between types of efficiency of production processes in order to discuss the rate of entropy increase.

[9] Barbier and Markandya (1990) developed a model of environmental management on these lines. For a review of the general class of such models, see Conrad and Colin (1987).

This is evidently the realm of value judgments involving two broad parameters: firstly, the interpretation of what constitutes value and, secondly, the role of time in production processes. With regard to the first, it is clear that concern for leaving the stock of natural capital untouched would imply the notion of 'preservation value' or 'option value'. Maintaining this capacity intact is likely to increase the possibility of achieving future development in the sense of "the capability of doing a wider vector of things".[10]

A lower discount rate implies more structured attention to the future through increased investment. It does mean, however, that, due to the accompanying higher levels of throughput, lower stocks of natural resources will be available in the future, as suggested by Becker (1982). This appears to go against the concern for maintaining a constant level of natural resource stocks. Furthermore, in order to determine both option values and rates of discount, present living standards are an important variable. If living standards are abysmally low, the present must take priority. As living standards increase, the relative impact of the future and of preservation efforts increases. Beyond a certain threshold, it makes sense to emphasize sustainability.

3. AN OPERATIONAL VIEW OF SUSTAINABILITY

Basically the above viewpoint maintains that value judgements cannot be made independently of the characteristics of the economic system to which they apply. Meanwhile, sustainable development has acquired an operational meaning in the context of production processes and their implication for providing a secure living.[11]

Conceptually, each eco-system can achieve sustainability at some level of productivity. The appropriate level is determined by a combination of factors, i.e. the productivity of the eco-system and its compatibility with the socio-economic system. From an operational viewpoint, it is sustainability at a high level of productivity which has attracted most attention. Witness, for example, the debate on the 'green revolution' in agriculture. When nitrate pollution, water-logging, and salinity threaten the production levels of energy-intensive, highly productive agricultural systems, the wasteful, unsustainable pattern of land use it involves is examined. On the other hand, the low level, long-term pattern of resource use of desert eco-systems is hardly noticed by development economists.

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[10] Sen (1988) adopts such a view of development. For a good exposition of the concept of 'option value', see Bishop (1982).

[11] See, in this context, Kadekodi (1991a,b) and Chopra and Rao (1991).

Both systems imply a degree of co-existence between eco- and socio-systems; the level of productivity at which they function could be changed through either component. The transaction cost of such changes may, however, not be warranted by the corresponding low productivity that would result.

In designing sustainable economies, the main thing is to develop rules for operationalizing the concept of sustainability. It is difficult to do this by means of any of the analytical approaches discussed above. Neoclassical resource management models, for instance, tend to reduce the concept to a one-dimensional constancy of output. Ecological, institutional, and social conditions for achieving this constancy of output are somehow assumed away. Thermodynamic approaches do not lend themselves easily to empirical verification. In this paper, therefore, we shall maintain a *focus on the sources of unsustainable development*, where sustainable development is viewed as a kind of robust equilibrium between economic and ecological systems. Robust equilibrium is seen as being two-dimensional; it ensures the population's livelihood whilst maintaining the natural capital intact. In an economic system that maximizes output and earning power, the deteriorating quality of natural resources may imply the start of an unsustainable course of development. Alternatively, if planned investment in an appropriate institutional framework ensures that natural capital is kept intact, outputs and means of existence may fall below a socially acceptable level and another source of disequilibrium or a movement towards a low-level equilibrium be initiated. Both these situations will have to be avoided.

In the following we attempt to find the causes of unsustainable development within the context of past development and the future outlook for Indian agriculture.

4 INDIAN AGRICULTURE: DEVELOPMENT PATTERNS IN THE LIGHT OF SUSTAINABILITY-LINKED ISSUES

Over the last 30 years or so, agricultural development in India has a number of achievements to its credit. Between 1962–65 and 1989–90 food grain production increased from 76.18 to 170.62 million tons. The annual compound growth rate of agricultural output averaged about 2.66% per year. Most of this growth is due to energy-intensive, irrigation, and fertilizer-based methods which were introduced in some areas in the mid-1960s. The social system, involving centralized research and bureaucratic management, combined with the eco-system (i.e. the soil and moisture condition), proved to be suitable for these methods.

To understand the spacial pattern of this development it is best to examine the agro-climatic regions into which the country can be divided.[12] These zones, which cut across political divides, provide a meaningful way of viewing agricultural

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[12] An agro-climatic approach to planning for agriculture has been adopted by the country's Planning Commission. See Planning Commission (1989).

TABLE 1. *Some Characteristics of Representative Agro-Climatic Zones*

	Zone 6 (Trans-Gangetic plains)	*Zone 7 (Eastern plateau region)*	*Zone 1 (Western Himalayan region)*	*Zone 2 (Eastern Himalayan region)*
1. Population density (per km^2)	328.87	136.07	61.46	125.83
2. Land use pattern				
Geographical area (000 hectare)	12508.73	39503.61	24573.80	27533.43
Forest area (%)	3.15	40.65	44.32	45.50
Not available for cultivation (%)	10.14	9.22	12.72	21.03
Fallow Land (%)	3.67	8.75	2.33	6.38
Net sown area (%)	80.01	32.08	18.02	18.70
3. Land productivity (Rs/hectare)	5195.00	2522.00	4047.00	3395.00
Productivity level (kg/hectare)				
rice	2939	909	1688	1074
wheat	2845	743	998	—
4. Irrigation (% of gross cropped area)	70.92	15.43	22.91	16.73
Fertilizer use (kg/hectare)	105.48	14.66	23.00	9.42
5. Total livestock (%)				
sheep	9.57	6.25	17.28	1.36
goat	7.67	23.93	21.75	19.93
livestock/gross cropped area (no./hectare)	0.56	2.81	5.21	3.21

Source: Planning Commission (1989b).

development, particularly if it is to be evaluated from the viewpoint of sustainability, and the associated linkages between eco-systems and socio-systems. Characteristics of four agro-climatic zones tabulated in Table 1 indicate the differences between them in terms of population density, land use pattern, land productivity, input use, and livestock population. Forest area varies from 3.15 to 45.5%; net sown area from 80.01 to 18.7%; irrigation from 70.92 to 16.73%; and livestock from 0.56 to 5.21 per hectare. However, a broad classification of the zones in terms of agro-climatic characteristics suggests the following patterns:

(1) River valleys and coastal plains.
(2) Ecologically fragile Himalayan, island, and desert areas.
(3) Arid and semi-arid plateau regions.

The constraints on output sustainability in each zone provide an indication of the ways in which sustainability, viewed as a desirable pattern of land use and other biomass resource use, may be frustrated. For example, in high productivity zones increased application of low priced inputs to ecological structures may result in erosion of such structures, threatening sustainability at high levels of productivity of land and livestock.

4.1. *Erosion of Sustainability in the High Production Regions*

The Trans-Gangetic plains (zone 6 in Table 1) are taken as an example of the success of Indian agriculture. Land productivity is over Rs 5000 (around US$190) per hectare with a cropping pattern in which cereals such as rice and wheat predominate. Rice and wheat production is around 3 tonnes per hectare. This zone constitutes a typical case of energy-intensive agriculture achieving a high level of productivity with 70.92% of gross cropped area being irrigated and fertilizer consumption of about 105 kg per hectare.[13] On the whole, the eco-system has proved to be well suited to the requirements of such energy-intensive agriculture, but sustainability issues have arisen in respect of land degradation and water use.

Land degradation in the form of water-logging and salinity was caused by high levels of irrigation.[14] However, state investment in canals systems in this region resulted in a rise in the water table, leading to a decrease in the cost of digging tubewells. As a result, vertical drainage improved as private investment in tubewells increased. Soil texture and land terrain were also favourable, and the use of both surface and ground water led to a systematic decrease in water-logging and salinity between the 1960s and 1980s. By 1984–85, these effects had fallen by 50% of their 1965–66 levels.[15] It can be argued in this case that land quality deterioration was arrested.

Alternatively, technological solutions such as horizontal drainage can also be used as degradation abatement for water-logged land. For land affected by salinity, gypsum-based methods are available. The cost of such degradation reversing technologies has been estimated[16] and some micro-studies have examined problems related to their large-scale adoption.[17] Although cost–benefit ratios are found to be acceptable, the technology has been adopted very selectively, i.e. in areas where incremental productivity gains can be more or less guaranteed. The implication of such behaviour is significant in the context of a technological solution to ecological problems. Not only must an effective abatement technology exist, it should be perceived to be effective. These conditions imply that the rate at which the socio-economic system adjusts to technological correctives for ecological constraints may be slow.

[13] See Table 1; data with respect to agro-climatic zones is from Planning Commission (1989a,b).

[14] Water-logging is a condition in which ground-water levels rise, resulting in a reduced land productivity and sometimes in its becoming unfit for cultivation altogether. Water-logging may be accompanied by secondary salinity, i.e. a rise in sub-surface salts which further reduces crop yields.

[15] See Chopra (1990). Estimates obtained from secondary data give orders of magnitude broadly similar to those obtained from National Remote Sensing Agency data quoted by the National Wasteland Development Board (1987). Land suffering from different degrees of degradation due to waterlogging and salinity in the north-western state of Punjab decreased from 68.15 thousand hectares out of a net sown area of 3803 thousand hectares to 23.03 thousand hectares with a net sown area of 4107 thousand hectares.

[16] See the Annual Reports of the Central Soil and Salinity Research Institute for these estimates.

[17] Singh and Bajaj (1988) provide a detailed analysis of the economics of reclaiming alkaline lands with the use of gypsum based technology in a neighbouring agro-climatic zone.

After the mid-1980s, in situations such as the water example described above, political and socio-economic constraints combined with eco-system constraints led to a deteriorating situation. The Trans-Gangetic zone is emerging as a water deficit region as a result of the cropping patterns adopted after extensive development of surface and ground water. Estimates of actual magnitudes may vary,[18] but there is agreement that there is 10–15% over use of ground water, caused mainly by the adoption of the water-intensive rice–wheat combination. Subsidized electricity for running tubewells, easy credit for their creation, and the implicit subsidy in the provision of canal water, all combined to encourage rice and wheat production.[19] Whether the political system will be able to decrease subsidies, and the economic system effect a shift to other, less water-hungry crop combinations, remains to be seen. Meanwhile, the sustainability of production at existing cost levels is clearly threatened.

4.2. *Erosion of Sustainability in the Mountainous and Sub-mountainous Regions*

Deforestation in the ecologically fragile Himalayan areas (zone 1 and 2 of Table 1) affects not only the mountainous region itself, but also the surrounding lower lands.

In the Himalayan areas forests constitute 42–45% of the geographical area and cultivated area is around 18–19%. In the hilly sub-zones of the Eastern Himalayas rainfall ranges from 2000 to 3000 mm per year, and from 200 to 400 mm per year in the high altitude and temperate valleys of the Western Himalayas. The heavy rainfall in the upper reaches occurs mainly during the three monsoon months. As the forest is cut down, the rain carries large amounts of top soil down into the valleys, rivers, lakes, and reservoirs. The storage capacity of these water-storing bodies is reduced leading to extensive flooding. If there is already high water availability in these down stream areas, water-logging is likely; if there is low water availability, dry ravines, such as those in the lower Siwaliks in the Punjab and the Haryana regions, may develop. Consequently agricultural production will decrease in both the uplands and the valleys. The other longer term impact is the erosion of the resource base for the future. It is estimated that about 16 tonnes of soil is lost every year from each hectare of the country's land.

This type of natural capital depletion is the result of inter-regional and inter-temporal developmental externalities which are the essence of the threat to sustainability. The link between deforestation and agricultural development has also been looked at as operating at the extensive and intensive margins of agricultural development. In a very direct sense, increases in net sown area have been the single most important cause of loss of forest cover.[20] It has also been

[18] One estimate (Dhillon, 1988) is that of a deficit of 60 million acre feet in a zone with a net sown area of about million hectares. Another is of about 20 million acre feet (Dhawan, 1988b).

[19] For a study of relative changes in irrigation subsidies and crop production, see Chopra (1989), in particular pp. 334–7.

[20] Khoshoo (1986), for instance, records that as much as half the total forest cover lost in the country has been brought under the plough.

hypothesized that agricultural growth after 1966 has not been sufficiently labour absorbing;[21] thus persisting rural poverty has added to the pressure on forest resources. As the opportunity cost of labour remained low, rural labour was used by contractors for tree felling.[22] Of course, the protracted exploitation of the forests could not have occured without increasing urban demand for wood for both fuel and industrial uses.

Two major strategies for resource preservation emerge from the preceding survey of the ecological and economic aspects of soil erosion, deforestation, agricultural growth, and persistent poverty: appropriate sites need to be identified to collect the rainfall run-off, whilst regeneration of the forest must be encouraged.

The problems of soil and water management for sustainable agriculture in the Gangetic Valley are also linked to those in the Himalayan regions. Large parts of the Middle and Lower Gangetic Valley suffer from an excess of water. Exploitable water in the lower Gangetic Valley at 119 cm per unit area is the highest in the country. This decreases as one moves westward, reaching a level of 41 cm in the upper Gangetic Plain. Land productivity, on the other hand, increases as one moves from east to west. The lower Gangetic Plain has a rice yield of 1.42 tonnes per hectare, whereas in the Trans-Gangetic Plain it is 2.94 tonnes per hectare. Further, the production impact of irrigation in this region is less than the national average, being about a tonne of foodgrain per one crop hectare brought under irrigation.[23] This low impact of irrigation is largely due to the flooding and water-logging hazards. Poor drainage results in excess water and, consequently, low yields. Laying a network of canals in such a region is certainly not desirable; tubewells are a possible alternative. Groundwater exploitation should be the strategy to follow in this region where 20–22% of the rainfall finds its way into the ground. So far, however, groundwater exploitation is only 25–32% of the identified potential in the lower Gangetic Plains.

Part of the reason for this low level of exploitation lies in institutional problems, one of which is the distribution of land ownership. Studies conducted in the lower Gangetic Plains have shown that private tubewells are viable if a 2 hectare plot benefits at a cropping density of 155%. Given that the average size of the holding in these regions is much lower than 2 hectares, it is little wonder that ground water has not been tapped as a resource by private entrepreneurs. Public tubewells, too, have been a failure. Group ownership and the subsequent emergence of a market in tubewell water may provide one institutional solution to the problems of water management in this region. Rural banks could finance such a group endeavour. Multi-purpose use of electric motors and diesel engines has also been suggested. Whatever policy mix is adopted, it is clear that changes in social systems are needed if optimal levels of water use is to be achieved.

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[21] See Rao *et al* (1988) and Rao (1990). This view is substantiated by the observation that, except in areas of intensive agricultural development, the real wage rate of male agricultural labourers has not increased over two decades.

[22] See Bhatia (1988) for such an hypothesis. Rao (1990) attempts an econometric study of the linkages and finds a positive and significant impact of rural poverty ratios on decline in forest area.

[23] See Dhawan (1989) for regional exploitable water and impact of irrigation.

In addition to such changes in the socio-economic system in the Eastern region, the flooding and water-logging problems of this region could be tackled by the construction of upstream reservoirs, large and small, and a programme of afforestation in the upper reaches. In terms of planning for increased production, it is necessary to see the Himalayan regions and the lower and middle Gangetic Plain as a single ecological unit. Inter-regional externalities are of crucial importance when dealing with ecological linkages in agricultural development and they must be taken into account in economic analysis of development strategies before choosing between alternatives. Viewing these regions as a single ecological unit contributes substantially to the development of ecologically robust policies that minimize the possibility of unsustainable conditions arising.

4.3. *Land Degradation with Low Productivity as the Source of Unsustainability: The Arid and Semi-arid Zones*

Despite the overall development picture, large parts of the Indian sub-continent (including agro-climatic zone 7 of Table 1) have lagged behind. Land productivity in a large part of this region is less than Rs 2500 per hectare (approximately US$ 83), and yields of both rice and wheat are between 0.6 and 1.2 tonnes per hectare. This region contains a large proportion of the country's degraded land; about 60% (as identified by the National Wasteland Development Board using remote sensing techniques) lies in these agro-climatic zones. Exploitable water per unit area is lower than the national average.[24] and the terrain is undulating. By virtue of their resource endowments, large parts of this plateau region are not suited to the adoption of an irrigation and fertilizer technology based on a state-run canal system or privately operated tubewells. Between 40 and 49% of the population is below the poverty line compared with 38% for the country as a whole, so increased income and productivity are essential.

No single development strategy is suitable for the plateau region and it is unrealistic to expect a uniform level of productivity. However, relatively low levels of productivity are significant when viewed as a means of reducing poverty and conserving resources.[25] The soil and water management techniques chosen must depend on local conditions. The watershed, an area of land with a common drainage, could constitute one area of operation. In regions with annual rainfall above 700–800 mm and with appropriate sites, successful strategies have been based on rainwater collection. Where there is lower rainfall, other measures have been tried. Increased agricultural productivity and soil protection has given rise to livestock rearing and secondary cottage industries.[26] Taken together this mix of activities has the potential for a sustained strategy of poverty alleviation.

There are significant benefits to be gained from such a strategy; cropping intensity may increase by 5–15% and incremental yields of 0.5–1.0 tonnes per hectare may be attained. The resulting 60–100% productivity increase in large tracts of arid and semi-arid land is significant for a number of reasons. As documented by the Planning Commission, a doubling of yield in these regions will make a significant difference to the nation's food grain budget. More importantly, this increase is compatible with the protection of the nation's soil and forest resources. In addition to increased grain production, the higher water table facilitates the raising of livestock, a factor that need to be taken into account in any evaluation of total strategy benefits.

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[24] See Dhawan (1989) for water availability by regions. Exploitable water is defined to mean ground water and surface water.

[25] See Kadekodi and Chopra (1990) for a detailed study of such a project aiming to do this in the eastern plateau region.

[26] For a study of the secondary activities generated by watershed development, see Chopra *et al.* (1990).

Studies can be categorized by the benefits they acknowledge. Ground water recharge, for example, is more relevant for the low rainfall regions. In the watershed regions horticultural development is aimed at preventing soil erosion. The latter policies are labour intensive and affect migration from the region. They also affect the availability of fuel wood and the livestock economy.

The limited rate of return evidence that exists confirms the efficiency of such investment. Evidence comes from the Operation Research Projects of the Indian Council of Agricultural Research, and from individual micro-studies of watershed development programmes involving soil conservation, aforestation, livestock improvement, and increased agricultural productivity. The investment required may vary from Rs 10,000 (US$ 300) to Rs 22,000 (US$ 750) per hectare (1986 prices), whilst overall rates of return of 13–19% can be expected. Results obtained from studies conducted in different parts of the arid and semi-arid regions of India are given in Table 2. The nature of the projects varies with the location, but increases in land use intensity and yield are reported from all areas.[27]

For a watershed management project to become the corner-stone of a sustainable poverty alleviation programme, a suitable socio-legal framework is needed. The ownership pattern within the watershed area is likely to be complicated, so decentralized decision making, participatory resource management, and consensual standards and rules are a prerequisite for success. Micro-studies have extensively documented obstacles to the emergence of such a set of conditions: entrenched centralizing forces such as the state and the market; internal conflict caused by differential access to resources. On balance, it seems as though considerable reorganization of the social system may be needed to attain the optimal level of development within the constraints imposed by the eco-system of this large arid and semi-arid region of the country. The joint evolution of the eco-system and the socio-political system is an enormous task, but it must be undertaken. A linear extension of canal water systems is not feasible or would be counter-productive within large parts of this region.

5. CONCLUDING REMARKS

In-depth studies of the course of Indian agricultural development reveals sources of unsustainability. In a few selected regions, the eco-system and the socio-

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[27] See also Chopra *et al.* (1990), Alagh (1989), and Vaidyanathan (1991).

TABLE 2. *Rain Water Harvesting and Soil and Water Conservation Techniques*

No.	*Project location and agro-climatic zone*	*Source*	*Nature of project*	*Impact on agricultural activity*			*Rate of return*
				increase in cropping intensity (percentage)	*incremental yield Percentage/ Quintals per hectare*	*gross return (Rs/ hectare)*	
1.	Maharashtra: western plateau and hill region	Saksena *et al.* (1989)	water reservoir	NA[1]	NA	3900–5000	B/C ratio: 1.28 IRR 12.33
2.	Maharashtra: western plateau and hill region	Nawadkar and Shaikh (1989)	land shaping, contour bunding moisture conservation	NA	NA	2455 (103% increase)	increase in net sown area of 14%
3.	Karnataka: southern plateau and hill region	Kulkarni *et al.* (1989)	soil and run-off conservation	7.45	Kharif Sorghum[2] 3.62, groundnut 3.26, chilli 12.44, cotton 16.14, Rabi Sorghum 1.44		net return increase Kharif sorghum

political system have changed together with little difficulty; some agro-climatic zones have experienced high agricultural growth rates even though externalities such as land degradation have been kept to a minimum. Even so, indications of over use of water are emerging in some areas within these zones. More significantly, indicators have emerged for the future course of agricultural development in other less-developed agro-climatic zones. To simply extend the earlier development programmes to large parts of the Indian subcontinent would not be advisable; constraints imposed by the eco-system may now be more binding. This is certainly the case for the arid and semi-arid parts of the country. The watershed, essentially a micro-unit based on an eco-system, will have to be adopted as the unit of development. For other agro-climatic zones a broad resource management perspective will require simultaneous consideration of two or more agro-climatic zones. Such eco-system-based planning should provide guidelines for the kinds of change needed in the socio-economic system in order to prevent an erosion of sustainability. If such changes are indeed made, both the erosion of natural capital and the reduction of living standards below socially acceptable levels can be avoided.

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5. Punjab; Himalayan foot hills	Singh *et al.* (1991)	live stock development, soil conservation				rate of return: 12.5% rate of return on forestry: 15.27%
6. Haryana: Himalayan foot hills.	Chopra *et al.* (1990)	water reservoir afforestation, creation of new institutions				rate of return: 19%

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[1] NA, not available; na, net addition in quintals per hectare.

[2] Incremental yield is in percentage; sorghum is a local millet grown in both crop seasons, Kharif and Rabi.

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Watershed Development
A Contrast with NREP/JRY

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A Contrast with NREP/JRY

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Wasteland and watershed development programmes, while creating some employment and assets for local population are designed basically to take advantage of the natural capacity for regeneration inherent in a biomass system. The paper makes an assessment of the implications of IRDP/NREP versus the land and water-related programmes for employment generation and natural capital regeneration, asset creation and environmental conservation.

TARGET-ORIENTED interventions to alleviate poverty have been the focal points in the Indian decentralised plans in the 80s. The object has been to provide assistance to the poor by way of asset creation or wage income through employment. Integrated Rural Development Programmes (IRDP) and National Rural Employment Programmes (NREP) were the earliest schemes in this direction. In the late 80s, the Jawahar Rozgar Yojana (JRY) was added to the list of such programmes. The concept of agro-climatic regional planning also emerged around this period. Afforestation through social forestry, watershed and wasteland development programmes focusing on land and water management were stepped up in a number of different regions. Such programmes also resulted in creation of employment and assets, while augmenting the quality of land and biomass generated therein. This paper aims at making an assessment of the implications of IRDP/NREP versus these land and water-related programmes for employment generation, asset creation and environmental conservation.

The NREP/JRY kind of intervention emphasises on employment and assets and its impact on environmental regeneration is only an afterthought. The consequent long-run impact on livelihoods is limited. Wasteland and watershed development programmes, on the other hand, while creating some employment and assets for the local population, are designed basically to take advantage of the natural capacity for regeneration inherent in a biomass-based system. The question which then arises is one of analytically characterising and empirically verifying the short- and long-run gains from these alternative rural development strategies.

The rural development programmes of the government of India can be classified into (1) those that are directed towards asset and employment creation such as IRDP, JRY, DPAP, DDP, (2) those that are designed to remove structural impediments to development such as the land reforms and marketing schemes, and (3) those that are of an enabling kind, i e, TRYSEM and other training-oriented programmes. The first set of programmes accounts for the larger part of the outlay incurred by the Ministry of Rural Development. The focus of the IRDP has been on credit for private assets for disadvantaged people.[1] A variety of assets have been identified qualifying under this scheme. JRY, on the other hand, has a focus on community assets including those that stress land and water development, social forestry and soil conservation. These aspects were also being focused on under the NREP and RLEGP in the 80s and the Drought Prone Area Programme and Desert Development Programme that have existed since 1973. It is to be noted however that the emphasis has shifted from privately-owned assets to community assets.

In the 70s watershed development was primarily the concern of the Indian Council of Agricultural Research (ICAR). A number of pilot projects were carried out at its regional centres with a focus on specific scientific experiments with respect to watershed characteristics. It was only in the early 80s when issues of land degradation became significant that the watershed was conceived of as a planning unit. Some pilot projects such as Sukhomajri in Haryana became significant as development interventions. Thus watershed management as a feasible policy of land and water management came into its own. The emphasis laid by the National Watershed Development Board on wasteland development on the basis of integrated regional planning and the notion of micro planning in different agro-climatic zones gave further fillip to the concept of watershed development.

NREP AND JRY

The NREP was launched in October 1980 (as part of Sixth Plan programme) and became a regular plan programme from April 1981. The programme was expected to generate additional gainful employment in rural areas, to the extent of 300-400 million mandays per annum, create durable community assets and improve nutritional status and living standards of the poor. As compared with the Food for Work Programme creation of durable public assets was the real distinguishing feature of the NREP. During the Seventh Plan, the broad objectives of the programme remained the same as in the Sixth Plan. NREP was to be implemented as a centrally-sponsored scheme on a 50:50 sharing basis between the centre and the states.

The programme had a substantial impact in terms of stabilising wages in the rural areas, containing prices of foodgrains and creating a wide variety of community assets which helped in raising the levels of living of the rural population.

Some specific features were built into the NREP as implemented during the Seventh Plan. The wage paid under the programme was to be at par with the minimum agricultural wage prescribed for the area. The quantum of foodgrains as part of the wage should be such as to be adequate for the family's need. In any case the foodgrain component should not exceed 2 kg per head per day. In order to ensure that benefits of this programme reached the weaker sections of the society, at least 10 per cent of the allocation under the programme was to be earmarked for utilisation exclusively on programmes of direct benefit to scheduled castes, e g, drinking water wells, environmental improvement works in harijan localities and housing for them. Another fraction of at least 10 per cent of allocation under the programme was to be specially earmarked for utilisation on programmes of social forestry and energy plantations. Even with these specifications, the NREP continued to be a programme for income and asset generation with limited focus on distributional and environmental aspects. Table 1 gives the expenditure, employment and assets created in NREP programmes between 1985-86 and 1989-90.

From April 1989, the two employment programmes in operation (i e, the NREP and the RLEGP) were merged together into a single rural employment programme known as Jawahar Rozgar Yojana. While the range of assets that can be created under JRY continued to be somewhat similar to that under NREP, preference was to be given to (a) works having potential of maximum direct and continuing benefit to the members of the poverty groups, and (b) assets which were or could be owned by or are assigned to groups of beneficiaries. High priority was to be given to infrastructural works which were required for poverty alleviation programmes.

It is to be noted that social forestry, tree plantation, soil conservation works, construction of village tanks and such other natural capital augmenting works have been a part of both NREP and JRY schemes. Community asset creation, significant in its own right, constitutes the rest of the programme. In addition to this, augmentation of natural capital-based infrastructure is also undertaken under the DPAP and the DDP. The DPAP is under implementation in 615 blocks in 91 districts and the DDP in 131 blocks in 21 districts. This is a programme focused on degraded environments and watershed developments. The core components of the programme are soil and land development, water resources and moisture conservation and development, afforestation and pasture development. Expenditure provided under these two programmes in 1991-92 was Rs 111 crore for 112 districts or approximately Rs 1 crore per district. In land and water resources development, achievement has been only about 29.61 per cent and 23.41 per cent of target in DPAP and 40.09 per cent and 45.07 per cent of target in DDP programmes respectively.[2] Afforestation has fared better with 65.19 per cent of target achieved under DPAP and 102.04 per cent under DDP.

In sum, programmes of rural development also have given attention to building up of natural capital. They have had, however, limited impact even in terms of area covered. Further, there have existed problems of the effectiveness of coverage, as pointed out in several evaluation studies.[3] It shall be argued in this paper that this is due to the lack of integration between generation of livelihoods and augmentation of ecologically degraded environments. Such integration can only be achieved if the linkages between livelihoods and improved environments are understood in the context of ecological entities such as watersheds or categories of wasteland.

PROGRAMMES OF WASTELAND AND WATERSHED DEVELOPMENT

The focus of programmes of wasteland and watershed development is different from that of NREP or JRY. Here the starting point is the existence of degraded land of different kinds and in different agro-climatic contexts. Degraded land together with its water and biomass resource is the base from where an income, asset and environment regeneration programme begins.

Soil and water conservation programmes for degraded land have existed in India on a limited scale. Till the end of the Sixth Five Year Plan (1983-84), nearly Rs 8,616 million had been spent on improvement of about 25.8 million hectares of the land with various soil and water conservation measures. In the earliest phases, such programmes were confined to the improvement of agricultural lands and contour bunding was the main activity. It was only after the mid-80s that the concept of integrated land-use planning was introduced and with it came the realisation that such development should involve both common and private lands.[4]

Such programmes gained momentum after some estimates of extent of wastelands in the country were made by the National Wasteland Development Board (NWDB) in 1985. One of the principal objectives of the Board was to identify wastelands in the country and to create reliable data base and documentation of wasteland development. This was done at two levels. The NWDB set up a task force which carried out a classification of various kinds of wastelands. Second-

TABLE 1: PERFORMANCE OF NREP 1985-86 TO 1988-89

S No	Item	Units	Year 1985-86	1986-87	1987-88	1988-89
I	Funds utilised	Lakh Rs	53,195	71,777	78,831	90,184
II	(a) Employment generated	Lakh mandays	3,165	3,954	3,708	3,950
	(b) Expenditure	Per manday of employment (Rs)	16.81	18.15	21.26	22.83
III	Assets created					
1	Area covered under social forestry	Lakh hects	1.16	2.18	1.67	1.50
2	Trees planted	Crore	42.46	70.10	43.97	46.19
3	Works benefiting SC/STs	Lakh Nos	0.90	1.24	1.50	1.75
4	Construction of village tanks	Lakh Nos	0.05	0.06	0.07	0.05
5	Area benefiting through minor irrigation and flood protection	Lakh hects	0.48	0.55	0.47	0.67
6	Construction of wells under Million Wells Scheme	Lakh Nos	—	—	—	0.12
7	Area under soil conservation works	Lakh hects	0.16	0.04	0.09	0.12
8	Drinking water wells, ponds, etc	Lakh Nos	0.21	0.16	0.41	0.38
9	Rural roads	Lakh kms	0.63	0.39	0.48	0.45
10	School building, balwadi, panchayats	Lakh Nos	0.51	0.28	0.28	0.27
11	Other works	Lakh Nos	1.00	1.36	1.69	1.95

Source: Government of India, Ministry of Rural Development Annual Report 1989-90.

TABLE 2: PERFORMANCE OF JRY 1989-90 TO 1991-92

S No	Item	Units	Year 1989-90	1990-91	1991-92
I	Funds utilised	Lakh Rs	2,45,854	2,58,648	2,74,198
II	(a) Employment generated	Lakh mandays	8,644	8,732	4,064
	(b) Expenditure	Per manday of employment (Rs)	28.44	29.62	67.47
III	Assets created				
1	Area covered under social forestry	Lakh hects	1 18	2.44	0.16
2	Trees planted	Crore	29.17	20.67	7.22
3	Works benefiting SC/STs	Lakh Nos	4.88	3.79	2.21
4	Soil conservation works	Lakh hects	0.43	0.16	0.07
5	Construction of village tanks	Lakh Nos	0.20	0.11	0.02
6	Land development	Lakh hects	0.13	0.12	0.05
7	Drinking water wells/ponds	Lakh Nos	1.54	0.73	0.18
8	Rural roads	Lakh kms	1.80	1.30	0.32
9	School buildings	Lakh Nos	0.34	0.36	0.09
10	Development of houses	Lakh Nos	0.09	0.12	0.04
11	Construction of houses	Lakh Nos	0.58	0.75	0.21
12	Panchayat ghars	Lakh Nos	0.09	0.11	0.02
13	Mahila Mandals	Lakh Nos	1620	1477	319
14	Sanitary latrines	Lakh Nos	0.34	0.32	0.06
15	Construction of wells under Million Wells Scheme	Lakh Nos	0.87	0.56	1.10
16	Houses under IAY	Lakh Nos	1.82	1.70	1.21
17	Other works	Lakh Nos	2.13	1.96	0.57

Source: Government of India, Ministry of Rural Development Annual Report 1991-92 ly, statewise forest and non-forest land was identified. Wasteland in the country was estimated at 129.58 million hectares with 93.69 million hectares being non-forest wasteland.

The ecological characteristics of the land base of the economy were spelt out further when the NWDB undertook intensive classification of different kinds of wastelands in 146 districts identified as having more than 15 per cent of área as wasteland. Thirteen categories of wasteland were identified and it was seen that the nature of degradation varied substantially across states and agro-climatic zones. About 60 per cent of the total degraded land was found to exist in the large- and semi-arid tracts of central, Eastern and southern India. Most of this land was part of the categories of 'degraded forests' and 'upland with or without scrub'. Alkaline and saline land existed in the coastal areas of Gujarat and in parts of the middle- and trans-Gangetic plains. The Himalayan foothills were affected mainly by soil erosion caused by water runoff, and the western dry region mainly by wind erosion. Table 3 shows nature and spread of wasteland by agro-climatic zones.

Since 1989, an integrated view of wasteland development as a people's activity has been taken. Wasteland development in this perspective focuses on afforestation, simultaneous creation of assets such as tanks, check-dams, water distribution systems, and adoption of soil and moisture conservation methods. The objective is to bring land back to its optimal level of biomass production. The nature of the assets required to ensure such revival of wasteland would necessarily depend on the kinds of wasteland as also the property rights existing thereon. This integrated perspective increases the potential for employment. Ecological linkages crucial for such an integrated view differ according to the nature of the wasteland. The categories 'upland with and without scrub' and 'degraded forests' are usually found in watersheds spread over different parts of the country.

Wasteland development in many areas takes the form of watershed development programmes. The programme here is focused on the watershed, an ecological unit comprising the entire land area draining into a common region.[5] The focus on watershed development enables a common linkage to be made between the somewhat disjointed development interventions in the area of soil and water conservation and wasteland development. It also links such interventions with an ecological view of the constraints on development by taking into account the water and land availability in the watershed. In this context, it is important to note that the agro-climatic regional planning approach of the Planning Commission has identified the east, central, west and southern plateau and the Gujarat plains as the regions where integrated watershed development is the relevant strategy.

Meanwhile, a number of watershed projects have been implemented both under different schemes of state and central governments and by different non-government agencies. Table 4 gives coverage, expenditure, employment and asset creation in some of these projects. Rates of return where available and other effects are also tabulated. The table reveals that each project has its own pattern of asset creation and consequently cost and benefit flows. As a category of development intervention, therefore, such projects do not fall into a strait-jacketed pattern.[6] Location determines the nature of the project. Assets created are usually rain-water harvesting ponds, check-dams, contour-bunds, fuelwood and fodder plantations. The type of assets differ according to whether the project is located in a water scarce, moderate rainfall or an assured rainfall zone. All assets are, however, natural capital augmenting. Their creation also results simultaneously in employment, increased cropping-intensity and increased yield per hectare. It is found that cropping-intensity increases by about 15 per cent, and yield by about three to four quintals per hectare. Soil losses are reduced substantially, ground water availability is augmented and a better green cover is provided for land, both by afforestation and natural regeneration.

The second-round effects of the initial benefits are reflected in the spread of activities such as basket- and rope-making, marketing of fruit and medicinal products, livestock development made possible due to the better output of fodder and grass from common lands so on. In the emergence of these effects of watershed project however, the existence or otherwise of people's participation is an important factor and the total impact of the project differs according to the extent of CPR and PPR linkages. Projects such as Ralegaon Sidhi, villages of Palamau and Sukhomajri which have witnessed the best effects have been characterised by the presence of a high degree of people's involvement.

NREP VERSUS WATERSHED MANAGEMENT PROGRAMMES

The question that arises when a development intervention is being planned is: how would watershed management programme compare with the alternative of an NREP-JRY kind of programme that creates employment and assets and in consequential increases in present and future incomes. The watershed management programme has an additional potential that of creating the possibility of a regeneration of natural capital. The question is framed in an analytical framework. The following symbols are used in developing the model:

Let X : One time finance for a programme.

α, β : Consumption component of X under the watershed and NREP programmes respectively. They account for immediate wage income from the programme, treated synonymously as consumption.

θ_w, θ_n : Incremental capital output ratios under the two programmes. These represent the potential of income generation through asset creation.

δ : Social rate of discount.

TABLE 3: NATURE AND SPREAD OF DEGRADED LAND AND IN INDIA BY AGRO-CLIMATIC REGIONS

Zone	Wasteland* (Lakh Hectares)	Major Forms of Degradation
Western Himalayan region	11.98616	Barren, rocky; snow-covered land
Eastern Himalayan region	16.02506	Shifting cultivation, degraded forest land
Lower Gangetic plains	1.22877	Upland (with or without scrub; degraded forest land
Middle Gangetic plains	3.44156	Degraded forest land; land affected by alkalinity/salinity
Upper Gangetic plains	6.9371	Alkalinity, salinty; gullied, ravinous land and waterlogged
Trans-Gangetic plains	1.430	Degraded pastures; upland with or without scrub
Eastern plateau	19.32150	Degraded forests; upland with or without scrub
Central plateau	41.28376	Upland with or without scrub; degraded forests
Western plateau	33.87416	Upland with or without scrub; degraded forests
Southern plateau	45.15793	Alkaline, saline land; upland with or without scrub
East coast plains	21.71539	Upland with or without scrub; degraded forest
Western plains and ghat	9.82109	Upland with or without scrub; degraded forests
Gujarat plains and hill region	16.22527	Upland with or without scrub; alkaline, saline land
Western dry region	6.98098	Sands, desertic; upland with or without scrub; degraded pastures
	235.4612 or	(23.546 million hectares)

Source: Compiled from National Wasteland Development Board (1987).

* Based on 146-district data only, identified as having more than 15 per cent of geographical area as wasteland.

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›ctor, Lok Jumbish Parishad, P. O. Box No. 411 GPO, Jaipur

Project Director

S(t) : Stock of natural capital at time (t).
Rate of regeneration or depletion of natural capital depending upon its sign.

The two kinds of interventions for poverty alleviation being considered here result in consumption benefits, both at the present and in future. Income generation is synonymous to consumption benefit, since the saving rate of the poverty class is zero. The present value of these can be represented by

$$\alpha X + \int_{t=0}^{\infty} (1-\alpha)\frac{X}{\theta_w} . e^{-\delta t} \, dt = X\left[\alpha + \frac{(1-\alpha)}{\delta . \theta_w}\right] \quad (1)$$

for watershed programme

$$\text{and } \beta x + \int_{t=0}^{\infty} (1-\beta)\frac{X}{\theta_n} e^{-\delta t} \, dt = x\left[\beta + \frac{(1-\beta)}{\delta . \theta_n}\right] \quad (2)$$

for NREP programme.

It can be easily seen that the two income benefit streams are identical as long as the ICORs are equal and exactly equal to the inverse of the discount rate δ. On the other hand, if the ICOR under watershed programme is lower than $1/\delta$ and that under NREP is equal or higher than $1/\delta$, then the present value income benefits under watershed programme is always higher. The reverse will be the case if ICOR under watershed programme is higher than $1/\delta$ and that under NREP lower or equal to $1/\sigma$[7]

It is known, however, as discussed in Section III that watershed development programmes are crucially different from other interventions in that they create the conditions for regenerating the natural system which is then a source of future consumption benefits. A third component of benefits accruing from such programmes is therefore the saving in investment funds which would otherwise be required to reach the same level of consumption in future. The regeneration rate of natural capital under the watershed programme is specified as:

$$\dot{S} = \delta S(t)\,[1 - S(t)/K],$$
where K is a constant. (3)

Equation (3) implies that regeneration of the natural system, once it begins, perhaps with the catalyst provided by watershed management, follows a logistic growth path.[8] The rate of growth of the resource stock is positive at first, reaches a maximum and then declines as the stock gets bigger. The maximum is reached when S(t) = K at an infinite time, which is perceived as the carrying capacity of the environment. The initial value of this stock is set to be K/(1+B).

We assume that the initial investment of X would take the village economy from a low level of natural capital S(o) to its full carrying capacity K. In a sense X/[(K-S(o)] = X(1+B)/KB is an average rate of investment to reach K starting from S(o) following the regeneration path given by equation (3). In the absence of such an initial investment X, the alternative would be to keep on investing every year so as to arrest degradation of natural capital reaching below S(o).

Regenerated natural capital through watershed approach is, in other words, a substitute for future investment in man-made capital or other asset creation to provide income to rural poor. The present value of saving of investable resources attributable to this third component, can be approximated as:

$$\int_{o}^{\infty} \left[\frac{X}{K - S(o)}\right] \dot{S}(t) . e^{-\delta t} \, dt \quad (4)$$

TABLE 5: PROSPECTS OF GAINS FROM WATERSHED PROGRAMME

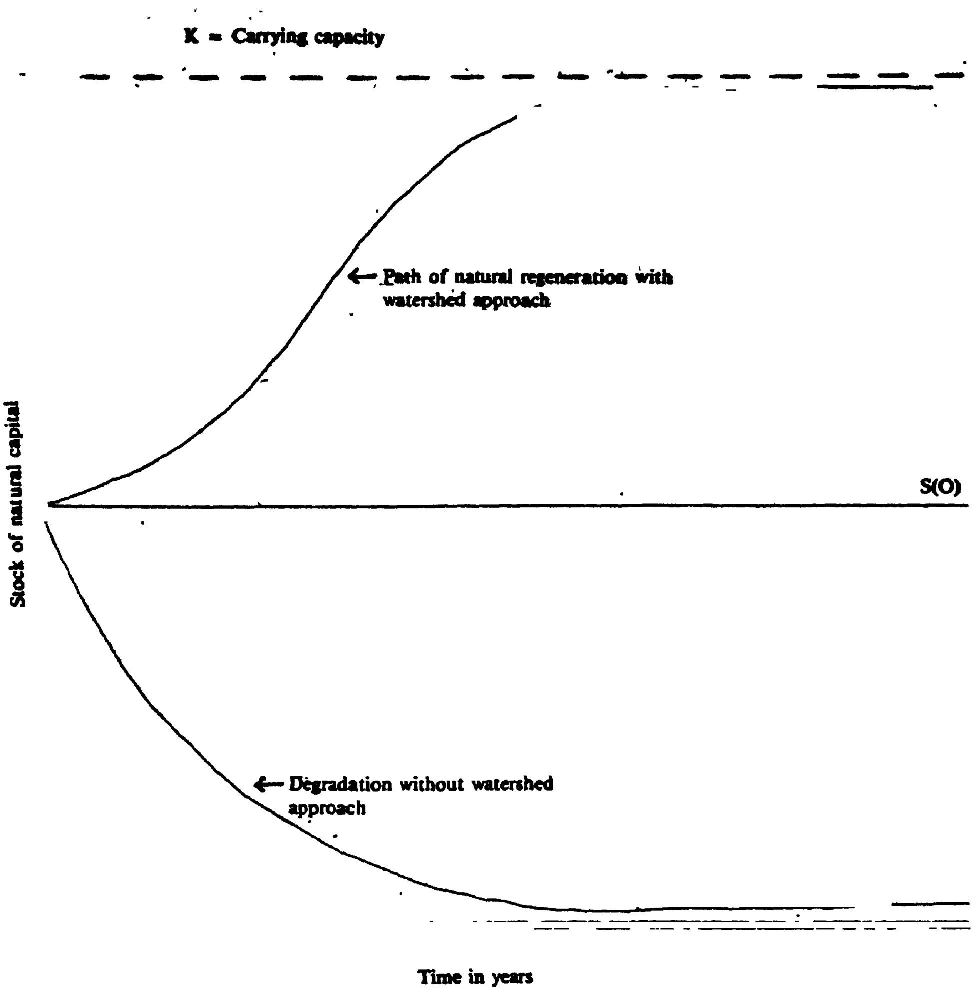
$B = \frac{K-S(o)}{S(o)}$	Present value savings from investing on natural capital in future attributed to watershed programme	Comments
0.25	31.73	For increased natural capital gap B, the savings from what would have been spent on regeneration decreases and at some high level of the gap, it even becomes negative, thereby measuring, actually increasing costs to regenerate.
0.50	6.16	
0.75	2.23	
1.00	1:00	
1.25	0.48	
1.50	0.22	
1.75	0.07	
2	−0.02	
3	−0.15	
4	−0.18	
5	−0.18	

TABLE 4: LAND AND WATER DEVELOPMENT PROJECTS

Sl. No	Name and Location of Project	Source	Nature of Project	Investment Cost Per Hectare Rs	Return Gross or Net (Rs Per Hectare)	Remarks Impact
1	Jalgaon (Maharashtra)	Saksena (1989)	Water reservoir		3,900 to 5,000	B/c ratio: 1.28 IRR 12.33
2	Ahmednagar (Maharashtra)	Nawadkar and Shaikh (1989)	Landshaping, contour-bunding, moisture conservation		2,455	B/c ratio: 1.03 increase in net sown area of 14 per cent
3	Ralegaon Sidhi (Maharashtra)	Patil (1988) Alagh (1990)	Nala bunding, contour-bunding, tanks	9,689		Increase in yield of jowar 100 per cent, bajra 50 per cent, drinking water available within 100-150 metres of each household
4	Naigaon (Maharashtra)	Datye (1988) Alagh (1990)	Percolation tank storage	11,364	212	Increase in yield of 7.25 quintals from a base of 1.2 quintals
5	Tejpura (MP)	SPWD (1988)	Watershed development	4,246	3,764	Doubling of bajra and jowar yields; 70 cross-bred cattle, plan for 2 lakh trees
6	Kolar (Karnataka)	Singh, K (1989)	Bunds graded contours farm ponds		1,970	Increase in yield of groundnut, figermillet pigeon pea
7	Sukhomajri (Haryana)	Chopra Kadekodi and Murty (1990)	Rainwater harvesting afforestation	22,221	7,979	Benefits to villages and to government IRR of 19 per cent
8	Kandi (Punjab)	Singh and Singh (1991)	Livestock development soil conservation, afforestation			Overall rate of return 12.57 per cent rate of to forestry 15.3 per cent
9	Samithed (Rajasthan)	SPWD (1988) Alagh (1990)	Afforestation cattle grazing	1,500		Returns in terms of plantation, rise in water table and fodder in 312 acres of land 78,000 samplings planted
10	Sikanderpur and Kotpurva	Singh and Bajaj (1988)	Usar reclamation project	11,220		255 days of grain requirement for a family plus 400 days of fodder for a pair of animals

Note: The details regarding sources of these studies are listed under references.

DIAGRAM: NATURAL CAPITAL GROWTH



Using the expression (3) for S(t), this saving can be deduced as:

$$\frac{X}{B^2}[B-(1+B)\log B] \qquad (5)$$

The total gain under the watershed approach would then be the direct income benefits under expression (1) plus the social natural capital gain in expression (5). As long as the present value total gain under a watershed approach is at least as great as that under an NREP programme, the former approach is worth considering to replicate in different regions in the country.

Is watershed programme universally relevant? It depends upon its regenerative potential. The savings of investment cost on natural capital regeneration attributable to watershed management, as shown in expression (5) depends upon the gap between the carrying capacity K and the current state of natural capital S(o). For higher is this gap, lower will be the savings in this investment cost, as can be seen from Table 5.

As can be seen from Table 5 for a critical, i e, disastrous natural resource degradation, the watershed approach may not be the most suitable option. But, for marginally degraded hilly tracts and forest slopes, the watershed management with employment and empowerment can become a more viable option.

Conventional JRY/NREP type of rural development interventions are based on the principle of adding to assets or incomes. Watershed management programmes and natural resource base augmenting development interventions which are designed to result in savings and investments as future interventions. This is the essence of self-sustaining strategies based on augmentation of natural capital. The present paper argues that, if natural capital regeneration follows a logistic path, there exists a set of conditions under which the latter kind of intervention is preferable. It appears that marginally degraded areas would benefit more from them in terms of saving in future investments and attaining their potential biomass and its sustenance. More heavily degraded areas may require a different, perhaps multi-dimensional and muli-disciplinary strategy.

It is worthwhile, in this context, to examine the agro-climatic regional planning approach. Large tracts in the arid- and semi-arid regions of the country have been identified as appropriate for an integrated watershed management approach. In the eastern plateau region, for instance, 105 thousand hectares have been set apart for such an approach.[9] The approach suggested in this paper requires a further ranking between sub-regions in this zone in terms of degree of degradation. Such a ranking would help in identification of less degraded areas where investment in natural capital augmenting watershed programmes would result in self-sustaining growth. Alternatively, more degraded regions require either conventional kind of JRY/NREP programmes on a continual basis or major afforestation and soil conservation programmes as specific forestry and land management options.

Notes

1 Of the outlay of Rs 3,508 crore in 1991-92, Rs 2,108 crore were on JRY, Rs 390.40 crore on IRDP and Rs 1,111 crore on the DPAP and DDP programmes.

2 See Annexure XXXII of Annual Report of Ministry of Rural Development, 1991-92.

3 See Dantwala (1985), Dreze (1990), Hirway (1985), Mahendra Dev (1990), PEO (1985), C H H Rao and P Rangaswamy (1988), RBI (1984), Subba Rao (1985) and IFMR (1984).

4 Number of Studies have shown the logical need to link CPR and PPR activities. See for example Chopra and Kadekodi (1990).

5 For a detailed description of watershed regional characteristics see Rajagopalan (1991).

6 For a review of these programmes, see Dhravanarayana and Sastry (1990).

7 If the ICORs are not the same in the two programmes, then also it is possible for the two income streams to be equal for some combinations of α and β. This will happen for infinitely many combinations of θ_w, θ_n, α and β.

8 Using equation (3) an expression for S(t) can be deduced as: $S(t) = \frac{K}{1+Be^{dt}}$ which is a logistic growth path for the natural capital, where $B=(K-S(o))/S(o)$.

9 See Alagh (1990) for the details. The eastern plateau and hill region consists of 10 districts of Orissa, nine in Madhya Pradesh, 11 in Bihar and three in Maharashtra.

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TOTAL PRIZE AMT. RS. 55 LAKHS

Price per Ticket Rs.5

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SHREE Monthly BUMPER DRAW

COMMON PRIZE Rs. 21 LAKH

FOUR PRIZES OF Rs. 1 LAKH EACH

FOUR PRIZES OF Rs. 25 THOUSAND EACH

- 20 Prizes Of Rs 5000 Each
- Also Many More Prizes
- Prizes Above Rs.5000 will be drawn from THE SOLD TICKETS Only
- The Numbers of winning tickets are drawn under the supervision of a panel of eminent personalities
- DRAW : THURSDAY, 15 th JULY 1993 AT BOMBAY

MAHARASHTRA STATE LOTTERY

DGIPR

THE SAKURA BANK, LIMITED

(Formerly known as THE MITSUI TAIYO KOBE BANK, LIMITED)

(Incorporated in Japan with Limited Liability)

BOMBAY BRANCH

BALANCE SHEET AS AT 31ST MARCH, 1993

(000's omitted)

	Schedule	As on 31.03.93 Rs.	As on 31.03.92 Rs.
CAPITAL AND LIABILITIES			
Capital	1	–	–
Reserves and Surplus	2	109,633	56,379
Deposits	3	1,762,542	1,089,378
Borrowings	4	–	519
Other Liabilities and Provisions	5	128,852	66,147
TOTAL		2,001,027	1,212,423
ASSETS			
Cash and balances with Reserve Bank of India	6	261,991	126,625
Balances with banks and money at call and short notice	7	202,345	2,207
Investments	8	568,477	376,772
Advances	9	852,187	625,646
Fixed Assets	10	42,197	46,418
Other Assets	11	73,830	34,755
TOTAL		2,001,027	1,212,423
Contingent Liabilities	12	702,284	585,427
Bills for Collection		130,287	248,357
Notes to Accounts	17		

Notes and Schedules to the accounts form an integral part of the Balance Sheet.

PROFIT AND LOSS ACCOUNT FOR THE YEAR ENDED 31ST MARCH, 1993

(000's omitted)

	Schedule	Year Ended 31.03.93 Rs.	Year Ended 31.03.92 Rs.
I. INCOME			
Interest earned	13	240,243	164,952
Other Income	14	26,052	29,398
TOTAL		266,295	194,350
II. EXPENDITURE			
Interest expended	15	99,034	73,472
Operating expenses	16	19,476	18,869
Provisions and contingencies		94,531	63,556
TOTAL		213,041	155,897
III. PROFIT/LOSS			
Net profit/Loss (–) for the year		53,254	38,453
Profit/Loss (–)		38,217	45,184
TOTAL		91,471	83,637
IV. APPROPRIATIONS			
Transfer to statutory reserves		10,651	7,691
Transferred to Head Office		–	37,729
Balance carried over to balance sheet		30,820	38,217
TOTAL		91,471	83,637
Notes to Accounts	17		

Notes and Schedules to the accounts form an integral part of Profit and Loss Account

As Per Our Report of Even Date Attached
For P. C. HANSOTIA & CO.
Chartered Accountants
Sd/-
(Ravi H. Vazirani)
Partner
BOMBAY
Dated: June 30, 1993

For THE SAKURA BANK, LTD.
Sd/-
(S. Yamamoto)
General Manager
&
Chief Executive Officer in India

Rural domestic sector

1.0 Overview

Sustainable and equitable development is one of the most critical challenges in the rural areas of most developing countries. Preventing resource degradation resulting from growing demands, and preserving valuable natural forests, and other fragile ecosystems from relatively low value uses is one of the immediate requirements for a sustainable world. After food, the most pressing concern in the foreseeable future would be to provide energy for subsistence as well as productive activities in the rural areas of the developing countries, including India. The population is expected to cross one billion by 2000 AD from the 1991 figure of over 853 million. Substantially higher energy would be required for both subsistence and economic development. Hence, a judicious choice of development patterns would be needed to achieve all these in a sustainable manner.

Rural energy scenario in India is dominated by the domestic sector, accounting for 75% of the total energy consumed. The fuel consumption pattern of the domestic sector is characterized by: an overwhelming dependence on biomass fuels, especially fuelwood; dominance of cooking among the end-uses accounting for over 90% of the energy consumed; collection of biofuels at 'zero private cost' with very little monetization; low penetration of commercial fuels owing to high costs and supply constraints; and the modest impact of renewable energy technologies. Despite the growing shortages of fuelwood due to resource degradation and consequent environmental concerns, biofuels continue to play the most important role in rural areas. Therefore, it is necessary to assess the future energy needs of the rural areas and the contribution of biomass in the fuel-mix so as to study the economic and environmental implications, and adopt suitable policy measures to meet the requirements in a sustainable manner.

2.0 Estimation of domestic energy requirements

The task of aggregating energy demand and its forecasting in time presupposes an understanding of the factors influencing the energy demand. Additionally, it demands a quantitative knowledge of the way these factors are likely to change over the time interval of the forecast.

The predominance of household energy requirement largely fulfilled by biofuels is a wellknown characteristic of the rural energy system in developing countries. Though the qualitative aspects of the rural energy consumption have been reasonably well documented and are understood fairly well, large degree of variability and inadequate quantitative understanding of the factors affecting the variability makes the task of aggregating and/or forecasting demand of such energy systems extremely difficult.

Further, to analyze issues related to energy demand, it is important to distinguish between three different elements of energy demand: *volume effects*, which are changes in the energy demand due to the expansion of the economy of the unit for which demand estimates are being made (which could include, but need not be restricted to, the changes in the number (population) of agents causing the demand); *structural changes* which are changes in energy demand due to basic parametric changes in the unit for which the demand estimates are being made; and *efficiency effects*, or the efficiency with which energy is utilized within the economy. In the context of the demand estimation for rural areas of India nearly all the estimates considered only the population changes insofar as volume effects are concerned. This is partly because there is very little evidence of a correlation between energy consumption and income in the rural areas, even if it can be established that the benefits of economic growth percolate to rural areas. The lack of information on the structural changes and the likely impacts of such changes is even more acute and, for the time being, inclusion of these effects with any degree of accuracy appears unlikely. In the absence of an understanding of the factors influencing energy demand, aggregating energy demand in the past has essentially used estimates of per capita energy consumption based on field surveys and trends in population growth.

It is worthwhile to also emphasize the distinction between *energy requirement* and *energy consumption* as the two have often been used synonymously in the past planning exercises in estimating and projecting rural energy demand. Most policy formulations dealing with rural energy sector have used energy requirements though substantial effort and progress has been made in attempting to understand issues related to biofuel consumption in rural areas. In the present work all reference to energy demand is linked to energy consumption based on surveys.

Summary of past demand estimates

Some of the major points regarding the past attempts to estimate demand on the basis of energy requirement (as opposed to consumption) for the domestic sector are as follows.

- All policy studies (ESI 1965; WGEP 1979; EDSG 1986), except the Advisory Board on Energy (ABE 1985), relied on energy consumption levels of the Energy Survey of India Committee (ESI 1965) of 510 kcal or 2.13 MJ per capita daily. The ESI, on its part, based the consumption figure on the National Council for Applied Economic Research (NCAER) surveys conducted during 1958-60.
- Though all the above studies had access to survey data at the district and state level, they appear to have used only national averages of the data, thereafter desegregating requirement at the state level. Obviously, information regarding the regional variation in requirements is lost in the process and the difference in the requirement is purely due to the difference in population.

The most crucial aspect, insofar as the energy policy and technology options are concerned, is the fuel mix for meeting the energy requirement. None of the studies following the ESI made any serious attempt to examine this issue. There have been no attempts to look at the variation in the mix of biofuels over time and the little effort that has been made in this direction was restricted to what role commercial fuels (kerosene and electricity) could play in changing the proportional contribution of different fuels -- the biofuel mix has been assumed constant over time in all studies. In many studies (for example, the ABE), the national average of the fuel mix was used to estimate state-wise requirements of different biofuels. As with the requirement estimates, this led to loss of information regarding the proportional contribution of different biofuels at the state level.

2.1 Energy Consumption in the Rural Domestic Sector

The most frequently used data on rural domestic energy consumption patterns came from the surveys of the National Council for Applied Economic Research (NCAER), the last of which was conducted in 1978-79, and published in 1985. This survey covered 13,010 sample households spread over 18 states of which the rural sample was 7500 households in 600 villages selected from 300 districts.

The other notable source of rural energy consumption data is from the Integrated Rural Energy Planning (IREP) exercise of the Planning Commission of the Government of India. This program attempts to prepare and implement energy intervention plans for an administrative cluster of about 100-150 villages (termed as a Block) and involves sample surveys for determining energy consumption patterns as a part of this exercise.

Apart from this, the Department (now, Ministry) of Non-conventional Energy Sources (MNES), ABE, and various state energy development agencies have commissioned over a large number village level surveys in different regions of the country. The data thus collected through the rural energy surveys conducted during 1985-92 in India was compiled and analyzed, to create a rural energy database (REDB) and to identify regional variations in energy consumption pattern (TERI 1992). Studies in the past had indicated that agro-climatic conditions are an important factor influencing the use of biofuels in rural areas. Both the level of biofuel use and the fuel-mix is believed to be influenced by the availability of different biofuels, which in turn, depends on the agroclimatic conditions. The results based on the analysis of the data compiled for 638 villages in 17 states spread over 14 of the 15 agro-climatic regions in the country comprised REDB. Desegregating these figures at the district level, the data was regrouped to arrive at state level consumption figures, presented in table 1.

Table 1. Household consumption of fuels for cooking and lighting end-uses (useful energy & physical units) 1991

State	FW kcal/hh/d	DC kcal/hh/d	AR kcal/hh/d	KR(C) kcal/hh/d	KR(L) kcal/hh/d	Electricity kcal/hh/d	FW kg/hh/d	DC kg/hh/d	AR kg/hh/d	KR(C) l/hh/d	KR(L) l/hh/d	Electricity kWh/hh/d
Andhra Pradesh	3353.50	922.71	2410.70	853.26	366.72	188.20	7.04	2.92	5.72	0.28	0.11	0.31
Arunachal Pradesh	4929.01	345.27	854.37	34.25	785.24	60.20	10.4	1.10	2.04	0.01	0.23	0.10
Assam	4935.37	344.79	853.18	34.25	785.24	60.20	10.4	1.10	2.04	0.01	0.23	0.10
Bihar	2905.93	547.08	659.05	152.27	930.30	504.80	6.11	1.76	1.60	0.06	0.27	0.84
Chandigarh	901.95	980.39	782.19	289.19	192.33	180.60	1.92	3.14	1.87	0.11	0.06	0.30
Dadra Nagar Haveli	2205.06	395.69	713.32	435.68	433.78	240.80	4.62	1.27	1.71	0.11	0.13	0.40
Daman	2272.34	397.14	716.10	435.69	433.78	240.80	4.79	1.27	1.71	0.11	0.13	0.40
Delhi	911.12	982.27	783.71	289.19	192.33	180.60	1.92	3.14	1.87	0.11	0.06	0.30
Diu	2271.88	396.90	716.10	435.69	433.78	240.80	4.79	1.27	1.71	0.11	0.13	0.40
Goa	2317.47	273.85	274.72	1261.37	374.98	180.60	4.4	0.88	0.66	0.39	0.11	0.30
Gujarat	2202.87	389.82	702.78	435.66	433.78	240.80	4.62	1.27	1.65	0.13	0.13	0.40
Haryana	959.50	978.61	780.79	289.18	192.33	180.60	2.04	3.14	1.87	0.08	0.06	0.30
Himachal Pradesh	2656.75	287.84	317.07	1394.50	11.42	120.40	5.61	0.94	0.77	0.40	0.003	0.20
J&K	2799.56	293.43	323.23	1394.57	11.42	120.40	5.89	0.94	0.77	0.40	0.003	0.20
Karnataka	2409.20	401.75	1604.50	1425.49	329.64	230.53	5.06	1.27	3.80	0.41	0.10	0.38
Kerala	2425.00	274.97	275.85	1261.38	374.98	180.60	5.11	0.88	0.66	0.36	0.11	0.30
Madhya Pradesh	4529.59	577.64	700.24	344.22	438.14	207.83	9.52	1.82	1.65	0.10	0.13	0.35
Maharashtra	2813.76	275.65	982.21	308.11	355.46	180.60	5.94	0.88	2.37	0.09	0.10	0.30
Manipur	4899.91	344.94	853.57	34.25	785.24	60.20	10.34	1.1	2.04	0.01	0.23	0.10
Meghalaya	4941.43	345.19	854.17	34.25	785.24	60.20	10.4	1.1	2.04	0.01	0:23	0.10
Mizoram	4846.80	342.98	848.71	34.25	785.24	60.20	10.23	1.1	2.04	0.01	0.23	0.10

State	FW kcal/hh/d	DC kcal/hh/d	AR kcal/hh/d	KR(C) kcal/hh/d	KR(L) kcal/hh/d	Electricity kcal/hh/d	FW kg/hh/d	DC kg/hh/d	AR kg/hh/d	KR(C) l/hh/d	KR(L) l/hh/d	Electricity kWh/hh/d
Nagaland	4935.82	345.26	854.35	34.25	785.24	60.20	10.4	1.1	2.04	0.01	0.23	0.10
Orissa	6711.87	744.70	1750.00	34.23	524.59	152.18	14.14	2.37	4.18	0.01	0.15	0.25
Pondicherry	4485.94	1562.83	3101.16	72.30	426.52	120.40	9.46	4.95	7.37	0.02	0.12	0.20
Punjab	965.23	979.98	781.88	289.19	192.33	180.60	2.04	3.14	1.87	0.08	0.06	0.30
Rajasthan	2025.53	1069.62	527.91	422.55	340.43	226.26	4.29	3.41	1.27	0.12	0.10	0.38
Sikkim	4759.72	342.89	848.49	34.25	785.24	60.20	10.01	1.1	2.04	0.01	0.23	0.10
Tamil Nadu	3509.59	1007.75	2428.86	724.39	378.39	175.05	7.37	3.19	5.78	0.21	0.11	0.29
Tripura	4952.96	345.27	854.37	34.25	785.24	60.20	10.45	1.1	2.04	0.01	0.23	0.10
Uttar Pradesh	1052.83	1561.78	331.68	401.22	574.67	633.89	2.2	4.95	0.77	0.12	0.17	1.05
West Bengal	2926.36	860.30	1331.15	374.28	733.71	65.00	6.16	2.75	3.19	0.11	0.21	0.11
All India	2816.35	808.94	1066.09	474.60	516.83	293.10	5.94	2.59	2.42	0.14	0.15	0.49

DC - Dungcakes, BG - Biogas plants, AR - Agricultural crop residue, KR - Kerosene, FW - Fuelwood

REDB confirms the predominance of fuelwood and the analysis indicated 95% confidence interval for per capita (pc) consumption (national aggregates) for cooking in the range of 1.10-1.34 kg/pc/d. The consumption of dungcake was lower at 0.40 - 0.49 kg/pc/d. The agricultural residue consumption was marginally higher at 0.47 - 0.63 kg/pc/d. The REDB estimates suggest the following with regard to the per capita biofuel consumption *across* agro-climatic zones:

- variation in the fuelwood used for cooking has a high degree of statistical significance;
- dungcake used for cooking has significant variation between the agro-climatic zones; and
- the variation in agricultural residues for cooking between agro-climatic regions is inconclusive.

The national level aggregates of different estimates of rural domestic energy consumption, are presented in table 2.

Table 2. Different national estimates of biofuel consumption in rural domestic sector (mt/y)

	Fuelwood	Dungcake	Crop residues
NCAER	93.3	83.2	36.7
REDB (low)	181.3	40.1	31.6
REDB (average)	252.1	106.9	99.2
REDB (high)	309.4	114.5	165.5
IREP	169.0	54.2	62.8

Though, of the three estimates, the REDB estimates appear to be consistently higher, the state-wise aggregates indicate that there is no such clear pattern. For example, the REDB estimates for fuelwood are higher largely due to high consumption in the states of Andhra Pradesh, Madhya Pradesh, Orissa, Tamil Nadu and West Bengal. The IREP estimates for fuelwood, on the other hand, are substantially higher for the states of Gujarat, Kerala, and Uttar Pradesh. Similarly, dungcake estimates of NCAER for Bihar and Madhya Pradesh are substantially higher than either the IREP or the REDB estimates.

Some of the likely reasons for the variations and the possible ways that a more consistent demand estimates could be made are as follows:

- NCAER data refers to the base period of 1979 whereas the IREP and REDB data are from the period 1985-91. Superficially, it would appear that biofuel use in rural areas has increased over time since NCAER estimates are consistently lower than either IREP or REDB data. However, a more probable reason for this has to do more with the difference in the nature of data as described above. The relative closeness of IREP and REDB estimates suggest that there is a need to recast NCAER data according to agro-climatic regions which would require district wise classification of the surveys.
- Experience indicates that variation in the biofuel use is an inherent characteristic of energy systems based on biomass even within an agro-climatic region. The need for an operational classification of agro-climatic regions makes it impossible to capture all factors which may influence biofuel consumption, particularly since the classification is used largely for planning agricultural development. There is, therefore, a need to specify the statistical variation in data collected through surveys and to use these in making demand estimates so as to make different estimates comparable.

2.2 Domestic energy demand estimation

In the present study, energy demand is projected for the terminal years of various Five Year Plans -- Eighth (1997), Ninth (2002), Tenth (2007), and Eleventh (2012) -- under the base case and an alternative scenario. The demand is estimated for the end-uses of cooking and lighting. The fuels considered are fuelwood, dung-cake, agriculture residues and kerosene for cooking, and kerosene and electricity for lighting purposes. The procedure adopted for projecting demand (base case and alternative case) is as follows.

- The REDB estimates of household consumption (in physical units) available at the agroclimatic zone level for the fuels was disaggregated to the district level for all the states.
- Rural population projections for the respective Plan periods (terminal years) were made at the district level, and aggregated at the state level. The decadal growth rate (GOI 1992) between 1981 and 1991 was compounded to project 1997 (terminal year of the Eighth Plan) rural population. For periods beyond 1997, the exponential growth rates were calculated for years 2002, 2007, 2012 and compounded to project populations of the same (table 3).

State/UTs	Rural population (million)					Households (million)				
Madhya Pradesh	50.84	58.08	64.91	72.59	81.21	9.24	10.56	11.80	13.20	81.21
Maharashtra	48.40	54.33	59.96	66.33	73.57	8.80	9.88	10.90	12.06	73.57
Manipur	1.33	1.58	1.82	2.11	2.45	0.24	0.29	0.33	0.38	2.45
Meghalaya	1.44	1.75	2.05	2.40	2.81	0.26	0.32	0.37	0.44	2.81
Mizoram	0.37	0.38	0.40	0.42	0.46	0.07	0.07	0.07	0.08	0.46
Nagaland	1.00	1.38	1.82	2.41	3.23	0.18	0.25	0.33	0.44	3.23
Orissa	27.42	30.52	33.36	36.48	39.90	4.99	5.55	6.07	6.63	39.90
Pondicherry	0.29	0.30	0.32	0.33	0.34	0.05	0.06	0.06	0.06	0.34
Punjab	14.29	15.88	17.35	18.96	20.72	2.60	2.89	3.15	3.45	20.72
Rajasthan	33.94	39.56	44.98	51.20	58.33	6.17	7.19	8.18	9.31	58.33
Sikkim	0.37	0.47	0.57	0.70	0.87	0.07	0.09	0.10	0.13	0.87
Tamil Nadu	36.78	39.84	42.60	45.56	48.73	6.69	7.24	7.75	8.28	48.73
Tripura	2.34	2.77	3.21	3.73	4.35	0.42	0.50	0.58	0.68	4.35
Uttar Pradesh	111.51	128.11	144.09	162.37	183.30	20.27	23.29	26.20	29.52	183.30
West Bengal	49.37	56.67	63.61	71.43	80.26	8.98	10.30	11.57	12.99	80.26
All India	628.46	710.17	788.79	879.19	984.40	114.27	129.12	143.42	159.85	984.40

Table 3. Population and number of households for different Plan periods

State/UTs	Rural population (million)					Households (million)				
	1991	1997	2002	2007	2012	1991	1997	2002	2007	2012
Andhra Pradesh	48.62	54.30	59.56	65.35	71.74	8.84	9.87	10.83	11.88	71.74
Arunachal Pradesh	0.75	0.89	1.03	1.19	1.38	0.14	0.16	0.19	0.22	1.38
Assam	19.93	21.35	22.62	23.96	25.39	3.62	3.88	4.11	4.36	25.39
Bihar	75.02	85.37	95.18	106.21	118.62	13.64	15.52	17.30	19.31	118.62
Chandigarh	0.07	0.14	0.25	0.47	0.86	0.01	0.03	0.05	0.09	0.86
Dadra Nagar Haveli	0.13	0.15	0.18	0.21	0.24	0.02	0.03	0.03	0.04	0.24
Daman	0.04	0.04	0.05	0.05	0.06	0.01	0.01	0.01	0.01	0.06
Delhi	0.95	1.77	2.99	5.03	8.47	0.17	0.32	0.54	0.91	8.47
Diu	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.01
Goa	0.69	0.69	0.70	0.70	0.70	0.13	0.13	0.13	0.13	0.70
Gujarat	27.06	29.71	32.15	34.83	37.77	4.92	5.40	5.85	6.33	37.77
Haryana	12.41	14.39	16.33	18.60	21.24	2.26	2.62	2.97	3.38	21.24
Himachal Pradesh	4.72	5.30	5.85	6.45	7.11	0.86	0.96	1.06	1.17	7.11
J&K	5.88	6.79	7.66	8.64	9.75	1.07	1.24	1.39	1.57	9.75
Karnataka	31.07	34.58	37.85	41.46	45.45	5.65	6.29	6.88	7.54	45.45
Kerala	21.42	23.05	25.31	28.99	35.08	3.89	4.19	4.60	5.27	35.08

- Thereafter, the consumption figures were used to project the likely demand for different fuels for the end-uses of cooking and lighting, at the district level, for the different Plan periods. The demand in physical units was converted to useful energy using appropriate conversion factors (see appendix).
- The district-level demand figures were then re-aggregated at the state level. Based on the state-wise demand, the state-wise per capita demand for fuels concerned was also computed.
- The impact of the penetration of RETs (renewable energy technologies), mainly biogas and ICs (improved chulhas) has been taken into account in the estimation. The savings accruing to the installation of biogas and ICs were discounted from the demand for cooking fuels only at the state level. The demand after the incorporation of RETs thus obtained was used to determine the state-wise per capita demand.

Assumptions made for the demand scenarios

Population projections

- The projections made for the respective Plan periods are assumed to remain the same in both the base case and alternative scenarios.
- The average household size is taken to be 5.5.

Energy demand projections

- The REDB consumption estimates used to project demand are assumed to remain constant for all the years concerned in the base and alternative cases. The changes in demand reflect change in population growth only.
- The end-use of lighting considers kerosene and electricity. The demand takes into account the 1991 consumption pattern (30% and 70% of the total households use electricity and kerosene for lighting, respectively). Keeping with this trend, an increase in household electrification by 5% and 10% for every Plan period is assumed in the base and alternative scenarios, respectively.
- All Plan periods account for the penetration of RETs -- biogas and ICs -- for end-use of cooking only, under different scenarios. It is assumed that in households using biogas, it replaces all cooking fuels; and in households using ICs, 20% savings in only fuelwood consumption is accounted for. The 1991 base case includes the installation (cumulative) of biogas plants and ICs up to March 1992 as per the MNES (Ministry of Non-

conventional Energy Sources) records. The 1997 demand incorporates the targets for installation of biogas and ICs as set by MNES. Functionality rates of 60% and 50% for biogas and ICs (fraction of working plants), respectively, are taken. The addition in installation of biogas plants in all Plan periods beyond 1997 is 200,000 and 300,000 plants per year for the base and alternative scenarios, respectively. For ICs, growth rates of 10% and 15% annually for the base and alternative scenarios, respectively, are taken.

Table 4. Demand estimation (Base case)

Year	Population	HH	FW	DC	AR	KR(C)	KR(L)	Elect
	million	million	mt/y	mt/y	mt/y	mt/y	mt/y	BU
1991	628.46	114.26	245.13	106.33	98.87	4.41	3.39	6.09
1997	710.27	129.12	270.40	118.72	110.39	4.92	3.57	8.07
2002	788.79	143.41	295.80	129.89	120.78	5.39	3.66	10.25
2007	879.19	155.85	315.60	138.68	128.95	5.75	3.74	12.85
2012	984.4	178.98	355.80	156.29	145.32	6.48	3.80	15.99

HH- Households, FW - Fuelwood, DC - Dungcake, AR - Agriculture Residue,
KR (C) Kerosene cooking, KR (L) Kerosene lighting, Elec - Electricity

Table 5. Demand estimation (alternative scenario)

Year	Wood	Dung	AgriR	Ker(C)	Ker(L)	Elec
	mt/y	mt/y	mt/y	mt/y	mt/y	BU
1991	245.13	106.33	98.87	4.41	3.39	6.09
1997	270.40	118.72	110.39	4.92	3.29	9.22
2002	288.17	131.14	121.97	5.43	3.05	12.81
2007	311.11	141.14	131.95	5.87	2.72	17.13
2012	344.34	162.5	151.18	6.72	2.28	22.38

3.0 Supply scenario

As has already been shown, an overwhelming proportion of the rural domestic energy is supplied by the biomass fuels. In the rural areas, the biomass fuel is mostly collected, at a 'zero private cost', and no formal distribution systems exist like in the case of commercial fuels. Hence, it is difficult to correctly estimate, either at micro or macro level, how much biomass is supplied from what type of land. This process is rendered even more difficult by absence of reliable biomass assessment techniques for large scale enumeration. Given this difficulty, most rural energy consumption surveys in the past assumed the supply to be equal to consumption. However, this is clearly not tenable in view of the implications on the sustainability of resource. The environmental implications of this scenario are discussed in detail in the next section. This section looks at the fuel-wise supply scenario in the rural domestic sector.

Fuelwood

Presently, the fuelwood consumption in rural areas is in the range of 100-250 million tonnes. However, a considerable amount of fuelwood is also consumed in the urban domestic sector as well as commercial establishments. Though, authentic figures are not readily available, it is estimated that nearly one-third of the total fuelwood is consumed in the non-rural sectors. Thus, the total consumption is in the region of 150-300 million tonnes.

On the other hand, the current sustainable production of fuelwood from forests, as estimated by the Forest Survey of India, is placed at 36 mt (52 million m^3) (GOI 1989). This includes the unrecorded production of fuelwood in the form of dead/dying and seasonally fallen wood which is collected from the forests as head-loads by the villagers living near the forests, and production from the plantations developed by the Forest Department[1]. The estimation from the so called "unrecorded sources" which include supply of fuelwood from private lands, gardens, trees around houses, shifting cultivation areas and the like has been put at 50 million tonnes per annum (Agarwala 1989). This brings the total sustainable fuelwood supply to 86 million tonnes.

[1] The figures from plantation cover the area under plantations during 1980-87.

Table 6. Statewise fuel supply estimates (mt/y)

State	Forest with > 40% crown density	Forest with 10-40% crown density	Plantations	Total supply (MT per annum)
Andhra Pradesh	1.876	0.5469	0.058	2.481
Arunachal Pradesh	4.091	0.3554	0.005	4.451
Assam	1.188	0.2227	0.015	1.426
Bihar	0.996	0.3346	0.042	1.373
Goa (D&D)	0.075	0.0064	0.001	0.082
Gujarat	0.467	0.1322	0.107	0.706
Haryana	0.025	0.0046	0.037	0.067
Himachal Pradesh	0.668	0.0717	0.021	0.761
Jammu & Kashmir	0.825	0.2268	0.009	1.060
Karnataka	1.864	0.1836	0.083	2.131
Kerala	0.632	0.0468	0.047	0.726
Madhya Pradesh	7.154	1.0100	0.254	8.418
Maharashtra	1.963	0.4440	0.154	2.561
Manipur	0.398	0.3094	0.008	0.715
Meghalaya	0.248	0.3143	0.005	0.567
Mizoram	0.321	0.3644	0.031	0.716
Nagaland	0.265	0.2698	0.009	0.544
Orissa	2.051	0.4915	0.086	2.629
Punjab	0.036	0.0216	0.046	0.104
Rajasthan	0.227	0.2452	0.046	0.518
Sikkim	0.180	0.0158	0.006	0.202
Tamil Nadu	0.732	0.1977	0.099	1.029
Tripura	0.137	0.0928	0.013	0.243
Uttar Pradesh	1.699	0.2740	0.225	2.198

State	Forest with > 40% crown density	Forest with 10-40% crown density	Plantations	Total supply (MT per annum)
West Bengal	0.254	0.0629	0.062	0.379
Andamans	0.494	0.0017	0.007	0.503
Chandigarh			0.0003	0.000
Dadra	0.012	0.0012	0.002	0.015
Delhi		0.0006	0.0005	0.003
Lakshadweep				0.001
Total	28.877	6.248	1.481	36.61

As far as the future is concerned, there are no estimates on the supply nor is any evidence of increased availability of fuelwood. Given the fact that the forest and other biomass resources are undergoing degradation in various degrees in different parts of the country, it is unlikely that the fuelwood supply would go up substantially. Therefore, it is possible that the sustainable yield of fuelwood would continue to be in the range of 85-90 million tonnes per annum, a far cry from the expected demand of over 270 million tonnes in the rural areas alone.

Crop residues

Crop residues are those plant materials that are left in the field or in agro-based industries after extracting the main crop produce. The materials are available in the form of straws, stalks, husk, leaves, fibrous material, roots and other parts of the plant material. No reliable data are available with regard to the quantity of crop residues used either as fuel or fodder. A rough estimate for non-fodder crop residues for the year 1991 is around 127 mt per year, nearly half of which is used up in the sugar industry. Based on the likely increases in the yields of non-fodder crops, the availability of crop residues has been estimated for the future years.

Table 7. Production and area under crops in different Plans

Year	Crop production ('000 tons)				Area under crop ('000 ha)	
	Maize	Pulses	G'nut	S'cane	Cotton	Jute
1990	8962	14265	7515	241046	7440	778
1997	8933	13854	8119	241042	7208	816
2002	9598	14549	8728	264514	7095	826
2007	10262	15244	9337	287986	6982	836
2012	10927	15938	9947	311458	6869	846

Table 8. Availability of crop residues in different Plans

Year	Crop Residues ('000 tons)						
	Maize	Pulses	G'nut	S'cane	Cotton	Jute	Total (mt)
1990	2688	18545	2480	79545	22320	2334	127
1997	2680	18010	2679	79544	21623	2447	127
2002	2879	18913	2880	87290	21284	2477	135
2007	3079	19817	3081	95035	20946	2507	144.4
2012	3278	20720	3282	102781	20607	2537	153.2

Dung cakes

There are about 272 million bovine animals in the country according to the Livestock Census of 1987. The total production of dung from these animals is around 1000 million tonnes per annum on a wet weight basis, which puts the dry dung availability at 200 mt. Half of the dung produced is assumed to be used for fuel purposes, that is, 100 million tonnes, which corresponds to the dung consumption figures provided by various estimates. The trend in bovine population of the last two, three decades shows stagnation, and therefore, the dung availability for fuel purposes is not likely to improve significantly in the future also. Therefore, at each terminal year in the Plans, the dung supply is assumed to be 100 mt.

4.0 Environmental implications of domestic energy use

As can be clearly seen from the demand projections, biomass fuels will continue to meet the bulk of the rural domestic requirements in the foreseeable future. Even with the most optimistic penetration levels assumed for commercial fuels, and renewable energy technologies, biofuels are still likely to account for more than 80% of the cooking and lighting needs, with firewood contributing half of the total requirement. On the other hand, the projected supply figures for different biomass fuels suggest that the present gap that exists between the demand and the sustainable supply will continue to widen in the future, with serious implications for the environment.

There are essentially two major environmental impacts due to energy use in the rural domestic sector: the impact on natural resource base; and the impact on quality of life. Given the supply-demand gap, these impacts are already manifest to some extent, though varying across ecological zones, and in a business-as-usual situation, are likely to be further accentuated with growing population pressure and consequent increases in the demand.

4.1 Effect on natural resource base

As is clear from the earlier discussion, fuelwood occupies a pre-eminent position among the biofuels, and during the 70s, it was commonly assumed that rural energy use was one of the prime factors for deforestation in most developing countries. The focus, of course, was also on the scarcity of fuel on account of deforestation. However, as more and more studies were conducted, the assumption on the correlation between fuel use and deforestation has weakened. For instance, the NCAER survey showed that nearly 56% of the domestic energy was supplied by fuelwood; but over 75% of this was in the form of twigs and branches, and further, about 57% of it was collected at a 'zero private cost' (NCAER 1985). Furthermore, the survey indicated that the felling of trees for fuelwood was an uncommon practice. On the other hand, there is also evidence of practices of fuelwood extraction (such as lopping of young trees which destroys the middle stock) exacerbating the degradation of biomass resource base, where it has already occurred.

India has experienced and is still suffering rapid forest denudation. Analysis of satellite imagery forest cover data, shows that from 1972-75 to 1980-82, the area of closed and open forest cover declined from 55.52 to 46.35 million hectare (or 16.9 to 14.1% of total land area), a loss of about 1.2 mha per year. In the latter period there was only 0.05 ha of forest per person, one of the lowest figures in the world. Closed forests (defined as a canopy cover of at least 40%) dropped from 46.42 to 36.02 mha, while the area of open and degraded forest rose from 8.77 to

10.06 mha. The balance consists of mangrove forests, which fell from 0.33 to 0.26 mha (CSE 1985). These losses are about seven times greater than previous official estimates for 'forest land', much of which has no trees on it.

Thus, there is little dispute regarding the fast deteriorating biomass resource base and its adverse impact on the rural lifestyles. Combined with the inability of the people to shift to commercial fuels like kerosene on account of low purchasing power and limited availability, the rural people are facing what many have termed the 'other fuel crisis' growing out of eroding biomass resource base.

Causes of resource degradation

Since the time of the British rule in India, commercial interest has been one of the prime reasons for degradation. To begin with it was resource outflow to the European countries. But the pattern continued even after the independence with a lot of thrust having been given to industrial development. Forest products were subsidized to the industries of pulp and paper, resin, gum and tannin, sports goods, matchbox and plywood in total disproportion to their real value. In India, studies such as in the Western Ghats and the hill regions of Garhwal and Kumaon, have provided concrete evidence on the role of commercial exploitation in the process of degradation.

In the last few decades, demand for agricultural land has also become an important factor leading to forest degradation. In the developing countries 60% of deforestation is attributed to the expansion of agriculture (World Bank 1992). Growing demand for food due to rapidly increasing population has forced encroachment, mostly illegal, on the forests. This is starkly evident in places such as North-eastern states where shifting cultivation is widely practiced. For instance, in the last four decades, the population of Arunachal Pradesh went up by 2.5 times, Meghalaya 3 times, Mizoram 3.5 times, Tripura 4 times, and Nagaland 6 times (Census 1992). This enormous pressure on agricultural land has reduced the cycle of shifting cultivation from 25-40 years to just 4-5 years, making the practice highly destructive. This, over-exploitation of land has rendered the agriculture unviable on one hand, and increased the demand for forest land to further expand the agricultural base, on the other.

Apart from commercial exploitation and agricultural expansion, forest denudation also takes place to some extent due to a variety of other factors like mining, construction of mega projects, etc.

And where forest depletion has already taken place, fuelwood demand may also be contributing to further degradation. A case in point is the fuelwood headloads: rural people carry fuelwood headloads to the nearby towns to sell, in the process creating a fuelwood market; and once, this becomes a regular activity as a reliable source of income, there would be a tendency to accelerate the process of degradation in the rural areas surrounding the towns. Nearly a third of the total fuelwood is estimated to be used in urban areas currently. The following table demonstrates the sharp reduction in the areas of closed forest within 100 km radius of nine principal cities in India.

Table 9. Decrease in closed forest cover around major cities

City	Forest cover (km^2)		Percent decrease (%)
	1972-75	1980-82	
Delhi	254	101	60
Jaipur	1534	786	49
Madras	918	568	38
Hyderabad	40	26	35
Nagpur	3116	2051	34
Bangalore	3853	2762	28
Calcutta	55	41	25
Coimbatore	5525	4700	15
Source: Bowonder et al. 1985			

In macro terms also, the fact that the present consumption level is at 250 million tonnes as against a sustainable yield of only 85 million tonnes indicates that the gap is being met from either 'unrecorded' or 'illegal' sources which may be contributing to the process of degradation heavily.

4.2 Quality of life

4.2.1 Health impacts of biomass burning

Burning of biomass fuels in inefficient cookstoves leads to high levels of indoor air pollution, causing a variety of eye and lung diseases. Though in rural areas of developing countries a large portion of time is be spent outdoors, certain indoor environments in these villages could be so smoky that they dominate the exposures of individuals who must work in these environments.

Pollutant concentrations vary spatially and temporally and people's activity patterns affect the exposures received. Total exposure assessment, at least in conceptual form, is comprehensive in nature and takes these variations into consideration.

There have not been many field studies of indoor air quality in rural areas of developing countries. In India, the National Institute of Occupational Health made measurements of TSP, sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) concentrations in kitchens where biofuels were being burnt in traditional stoves. They found that TSP levels were much higher than the SO_2 and NO_2 levels (INIOH, 1980).

Table 10. Air quality measurements in kitchens where various biofuels are in use.

Cooking fuel	TSP (mg/m^3)	SO_2 (mg/m^3)	BaP/TSP (mg/m^3)
Cowdung	16 (9.6-20)	0.24 (0.29-1.1)	0.56 (0.21-0.74)
Wood	7.2 (4.7-11)	0.17 (0.02-0.76)	0.19 (0.15-0.22)
Wood and cowdung	21 (10-58)	0.27 (0.03-1.3)	0.53 (0.07-1.7)
Source: INIOH, 1980; Aggarwal et al., 1982.			

The first field study of exposure was conducted in 1981 in Gujarat. This pilot study measured the exposure of cooks to TSP and the concentration of carbon monoxide (CO) in the cooking area. In addition, the TSP filters were analyzed for BaP (Smith et al., 1983). The findings confirmed previous hypothetical calculations that village cooks are, indeed, exposed to high pollutant levels on a regular basis (Smith et al., 1981). People cooked indoors invariably but ventilation conditions did vary over the year since, during the monsoon season, skylights and openings in the walls and roof of the kitchen were blocked. Smith et al. (1983) found extremely high TSP exposures (peak of 56 mg/m^3) under these conditions. The seasonal variations in exposure, then, can be quite substantial.

Exposure to biomass pollutants leads to a variety of lung and chest-related problems. Biofuel smoke has been established as a risk factor causing Acute Respiratory Infections (ARI), the chief cause of infant mortality in the Third World, accounting for nearly 650,000 deaths in India annually (Smith 1993). The incidence of *cor pulmonale*, a heart disease, is found to be high among north Indian women. Biomass pollution has also been linked to pregnancy related problems among women. Given that, the health facilities are still not of very high quality in rural India, any energy intervention program designed must consider health improvement as a major objective.

4.2.2 Drudgery

One of the important manifestations of a deteriorating fuel supply situation is the increased time and travelling distance for women and children who collect the fuelwood. In most rural areas, especially hilly regions, women usually participate in both economic and non-economic activities, and increased collection times have a high opportunity cost, though it may not be easy to quantify it. However, the increased burden will have a deleterious effect on the health of the women, education of the children, general well-being of the family, etc. The following table illustrates this problem in different parts of the country.

Table 11. Time and distance travelled by women

Place	Time spent	Distance travelled
CHAMOLI (Hills)		
a) Dwing	5 hrs per day	> 5 km
b) Pakhi	4 hrs per day	> 3 km
GUJARAT (Plains)		
a) Forested	once in 4 days	--
b) Depleted	once in 2 days	4-5 km
c) Severely depleted	4-5 hrs a day	--
M.P. (Plains)	twice a week	5 km
KUMAON (Hills)	thrice a week	5-7 km
KARNATAKA (Plains)	thrice a week	5.4 km/trip
Garhwal (Hills)	5 hrs per day	10 km

5.0 Past intervention efforts

Though there has not been a uniform rural energy policy the Centre, several technologies and programs have been promoted in India which have had mixed results. Some of the important programs have been briefly mentioned here[2].

b) *Rural electrification.* This has been a major rural energy program launched by India in the 60s to energize the villages by extending the electricity grid. By 1992-93, it was claimed that more than 84% of the villages have been electrified. However, several critics have pointed out that an 'electrified village' did not automatically mean electricity to all the households; in fact, it is estimated that only about 30% of the total rural households have access to electricity.

a) *National Project on Biogas Development.* Having been launched in 1981 by the Ministry of Non-conventional energy Sources, this program attempted to push biogas technology, which was already popular in the rural areas, in a big way. By now, nearly 2 million biogas plants have been installed in the country.

b) *National Program on Improved Chulha.* Design modifications were made to remove smoke from, and make the traditional cookstove more efficient, a national program was launched in 1983 by MNES which installed about 16 million stoves so far.

c) *Other renewable energy technologies.* Solar photovoltaics, solar thermal systems, wind pumps, gasifiers, etc. have been tried out to meet end-uses such as lighting, water pumping, etc. But the installation has been most on a pilot scale for these technologies to make any mark.

d) *Integrated Rural Energy Planning Program.* Promoted by the Planning Commission of India, IREP envisaged comprehensive energy planning and implementation of an optimal intervention program with a combination of technologies at the block level (block is an administrative unit with typically 100-500 villages). So far, over 250 IREP blocks exist in the country.

e) *Urjagram program. Urjagram* means energy village. This is a concept promoted by MNES which envisages making specific villages self-reliant in their energy needs by installing a combination of renewable energy technologies. There are nearly 430 such villages in the country.

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[2] Some of these programs have been reviewed in the chapter on Renewable energy technologies.

Apart from these, there have been programs such as social forestry, wastelands development schemes, energy plantations, etc. which had fuelwood supply as one of their objectives.

Over the years, these programs have provided some benefits, but have also suffered from various technological, social, cultural and institutional shortcomings which have limited their impact. But the significant fact is that, the combined impact of all these programs is still quite insignificant compared to the magnitude of the rural energy consumption. For instance, biogas plants and improved cookstoves together, the largest dissemination effort in the rural areas, are estimated to save no more that 10 million tonnes of fuelwood out of the total demand of over 250 million tonnes. Thus, any assumptions made in terms of enhancing the magnitude of these efforts manifold appear unrealistic. Therefore, in this chapter, emphasis has been given more on the different institutional reforms that are required to be effected in the sector, rather then providing quantitative targets to be achieved to make the energy system sustainable.

5.1 Environmentally sound energy strategy

It is clear from the above discussion that fuel substitution in terms of commercial fuels replacing biomass fuels is a very distant option, if at all. Therefore, the strategy to meet the energy needs in the rural domestic sector has to revolve around biomass, whether to adopt conservation measures, or augmentation activities. Some of these options and the institutional reforms necessary for making them effective have been discussed here.

a) *Fuelwood plantations.* As mentioned earlier, augmentation of fuelwood has been attempted through various afforestation programs in the past. People's participation, and choice of appropriate species have been the major constraints in the success of these programs. Therefore, utmost importance should be attached to attracting local involvement in these efforts, if they have to be successful. The concept of joint forest management (JFM), which brings together the local people and the forest department to manage the natural resources jointly, is assuming increasing significance in a few parts of the country. This not only envisages resource management through better planning to meet different requirements, it also plans for income generating activities among poorer sections of the population so that their dependence on the resource base is reduced.

b) *Promotion of biogas plants and improved cookstoves.* Though these two technologies have had a limited impact so far, they have a large potential in view of their environmental benefits. This is especially so as they have already gained good recognition, and even acceptance, in some parts of the country. But for these to be successful, a need-based research and development[3], strengthening the training infrastructure, increasing involvement of local organizations or creating local managing bodies, creating awareness among the population regarding the quality of life, etc., have to be taken up on a large scale[4].

c) *RETs for decentralized power generation.* One of the major problems in rural electrification has been the quality of supply. Extending the grid to remote areas is not only cost prohibitive, but the supply is erratic and of poor quality. Therefore, the option of decentralization power generation through renewable energy technologies has to be explored seriously. This can not only provide power to the remote and inaccessible areas, but also strengthen the grid wherever it is possible to connect. Mini-micro hydro power and biomass gasifiers are the RETs worth exploring seriously in this context. Wind and solar photovoltaics are also feasible options where potential exists. But for these to succeed, apart from economic and other considerations, there is a need to make them an integral part of the rural electrification process. For instance, though micro-hydel programs are implemented by state electricity boards in several states, they are not treated as serious programs given their small scale. This would be reflected in inadequate allocation of funds, shortcomings in operation and maintenance, etc. Therefore, it is imperative to ensure adequate coordination among various agencies implementing these programs (state electricity boards, energy development agencies, government departments, etc.).

5.2 *Institutional aspects*

Apart from the measures suggested above, there are some more aspects that need to be paid attention to, to improve the rural energy system.

a) *Decentralized rural energy planning.* One of the problems with most intervention programs has been that most of them were designed and executed independently without any coordination or integration at any level. This often resulted having programs where the need was not commensurate, or in more than one program targeting the same group, leading to setbacks. Therefore, it is important to introduce planning and implementation of rural energy programs at the decentralized level which will incorporate the targets for different technologies in an integrated manner for a given region. Though area-based programs like IREP and *Urjagram* have been promoted, they have not made any attempts to integrate the technology-based interventions. The result has been two distinct streams of area-based programs and technology-driven programs. But for decentralized energy planning to become a realistic concept, it is necessary to strengthen the planning, technical and operational skills at the grassroots level.

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[3] For instance, development of different feedstocks to be used in biogas plants will increase the potential exponentially, which can be used for not only cooking but also for lighting, shaft power, etc. Such a development makes biogas an extremely important option.

[4] Detailed recommendations to improve the promotional strategy of these technologies have been provided in the chapter on Renewables.

b) *Capacity building.* In order to facilitate such a decentralized planning as outlined above, it is necessary to create local level institutions, or strengthen the existing ones. The government of India has recently promulgated the *Panchayati Raj* Bill, which envisages enhanced powers and financial allocations for *Panchayats* (village governing bodies) to step up the efforts of rural development. It would be appropriate to use these institutions to promote energy promotion activities as part of the overall development process.

Another measure that needs serious consideration is encouraging the rural entrepreneurship. Market orientation is the professes policy of government, which needs to be explored to be promoted in promoting the technologies which have matured and gained acceptability in the rural areas. Biogas technology has already achieved in a few pockets of the country. It is necessary to develop a suitable regime of fiscal and other incentives to encourage this activity.

c) *Review of promotion policy.* Most energy development programs have so far been promoted in the rural areas with state assistance in the form of cash subsidies. However, in a recent shift in policy, most of this assistance has been done away with or curtailed drastically. But, the debate on 'subsidy or no subsidy' notwithstanding, it is necessary to review this entire policy in view of the likely impact this would have on the programs, especially given the fact that, large indirect subsidized continue to be offered to various commercial fuels. It is not out of place to mention here that there is also a need to look the issue of energy pricing in general to rationalize some of the distortions that exist in the system.

Most of the measures suggested here are qualitative in nature, mostly at the institutional level. Therefore, it is difficult to envisage at this stage what will be their impact, if they are implemented, on the overall energy scenario as far as rural domestic sector is concerned. However, given the magnitude of the problems, it is imperative to implement all the measures in the most effective way possible.

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ENERGY & ENVIRONMENT INTERFACE IN INDIA : CASE OF COAL BASED SYSTEMS

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Although the average per capita consumption of energy in India still remains well below that of the western world, there has been spectacular increase in energy generation during the past four decades. Irrespective of the dwindling reserves of fossil fuels, it does not appear that in coming years there will be any restraint on energy demand and generation. Even though we can ill-afford to do so, energy conservation and energy efficiency have not yet taken roots in our development models and life styles.

About two-thirds of energy consumption in the country are met from commercial sources such as coal, lignite, oil, natural gas, hydel power and neuclear power. Among the commercial sources, coal has been and will remain as a major supplier of energy requirement in the coming years.

Electricity is a clean form of energy during its use; but, this is not so in the process of its generation. This is particularly so in case of coal based thermal power stations which are faced with a host of environmental problems because of the effluents, emissions and solid wastes. The nature and extent of pollution problems in handling of coal, right from the mines to the thermal power stations for conversion to electricity, can hardly be over-emphasised.

The pollution problems are aggravated by the high ash content in coal which has become a major issue of environmental concern. Barring a few exceptions, we have not yet been able to make a positive effort for dealing with problem of fly ash and bottom ash. The possibilities for utilisation of ash are known but these are not practised ostensively for economic reasons. It is often argued that utilisation of ash is not an economically viable proposition and only a small portion of the ash could be utilised primarily for land-filling purposes. This is an issue which requires a much more careful attention than that has been so far given. It is unfortunate that the ash is considered only as a waste and not as a raw material. The Ministry of Environment and Forests insists on a phased plan for utilisation of ash as one of the conditions for environmental clearance of thermal power projects. There is no reason why power generation alongwith utilisation of ash cannot become a viable industry provided there is motivation and innovation.

As yet, there has been no meaningful effort to reduce the ash content of coal right at the source (pit head) instead of carrying as much as 50% ash through a long distance for generation of power.

Fortunately, Indian coal has relatively low sulphur content. Hence, some of us tend to believe that we may not face the problem of acid rain and adverse effect of sulphur dioxide emission. This is not the case particularly in areas with conglomeration of thermal power stations such as Singrauli and in ecologically sensitive areas.

Relatively cleaner and clean-up technologies are available. These include the following:

1. Coal gasification and combined power cycle generation
2. Fludised bed combustion
3. Flue gas desulphurisation
4. NOx reduction technologies

The efforts for adopting cleaner and clean-up technologies have been far from adequate. It is necessary to find ways and means for improving the technologies which will not only reduce the environmental problems but also increase the efficiency of energy generation. Some of the pre-requisites for pollution control in coal based power stations are discussed in the note (attached).

PRE-REQUISITES FOR POLLUTION CONTROL IN COAL BASED THERMAL POWER STATIONS

CENTRAL POLLUTION CONTROL BOARD
DELHI

1. INCREASE OF PLANT LOAD FACTOR IN COAL BASED THERMAL POWER PLANTS

The average Plant Load Factor (PLF) for the thermal power plants in India is around 55%. But, these plants operate with varying efficiency ranging from a meagre 10 % to as high as 75% PLF. The reasons attributed to poor efficiency include: (i) continued operation of plants (more than 20 years old) which have outlived their life and (ii) erosive characteristics of coal and (iii) poor maintenance. Statewise Plant Load Factor (PLF) in the coal based thermal power plants during 1990-91 and 1991-92 is given in Annexure-I. Millions of rupees have been invested in power plants. However, due to their operation with poor plant load factor and high transmission loss, there is chronic shortage of power. Hence, we are required to invest in new facilities for power generation which involves huge expenditure.

A reasonably well maintained system should operate at over 80% over the first 10 years down to 75% at the end of the 20th year and down to 50% at the end of the 30th year. A life extension programme can restore the plant capacity to its original level for another 20 to 30 years (EPTRI Chart, USA). There is no reason why this cannot be achieved in India.

It is estimated that the cost of retrofitting (including environmental updating to meet the norms) would be not more than Rs.1 crore per MW ($0.33 million), against the cost of investing in new facilities at Rs.3.5 crores to Rs, 4 crores per MW ($ 1.16 million to $ 1.33 million). With an investment of Rs. 12400 crores to optimise the existing plants, it may be possible to generate as much as 12,000 MW of additional power and concurrently achieve significant reduction of particulate matter and sulphur dioxide emission. On the other hand new facilities for generating 12,000 MW power would cost over Rs. 40300 crores and the problems of pollution from the existing plants will continue.

(Action : Ministry of Energy/Central Electricity Authority/State Electricity Boards)

2. DECREASE OF TRANSMISSION AND DISTRIBUTION LOSS OF ELECTRICITY

The transmission and distribution loss in India is of the order of 23 to 24 per cent. In this context, it may be relevant to refer to the figures in some other countries which are as follows:

Thailand	18%
Philippines	18%
Korea	12%
Taiwan	9%
USA	7-8%
Japan	7-8%

It is estimated that one per cent saving in transmission and distribution loss would be equivalent about 380 MW (Source : TERI Energy Data Directory and Year Book 1990-91). The equipment and technology is known and the investment could be recovered, in many cases, within a year. The potential for saving of power by bringing down the transmission and distribution loss is around 4000 MW, and this will also lead to reduction of pollution to the tune of 24,000 MT of dust and 570 MT of sulphur dioxide per day which will be otherwise generated during production of additional 4000 MW of electricity.

(Action : Ministry of Energy/Central Electricity Authority/State Electricity Boards)

3. BENEFICIATION OF COAL FOR POWER STATIONS TO REDUCE GENERATION OF PARTICULATE MATTER AND SULPHUR DIOXIDE

The average ash content in the inferior grade coal (E, F & G) primarily used for power generation which is now around 38% is likely to increase at the rate of about 1% per annum and in a few years it may be around 42%. The additional load of incombustible materials like shales/stones in coal will thus increase and result in various problems including environmental pollution. This will also cause waste of energy in transport of sterile material over long distances. This will also mean extra cost to the economy besides constraint of transport and added air pollution.

It is in this context of energy conservation, environmental pollution control and cost of transport, beneficiation of lower grade non-coking coals for use by power sector is significant. Even going by the presently adopted policy of limited beneficiation to remove extraneous matter and reducing the ash to 34 % for power plants situated at distance of over 1000 kms, from the coal mines, it would mean substantial relief in terms of reduced railway tonnages as well as a positive improvement in the environment around the power stations. About 15 to 20% rejects would be disposed off at the mine site where its disposal is much easier.

The other gains/advantages of beneficiation of non-coking coals (limited beneficiation from 40-42% ash to 34%) based on pilot project for beneficiation of coal at Nandan Washery and its use at Satpura Power Station on trial basis are as follows:

i) Improvement in plant utilisation factor for the unit (73% to 96% in trial).

ii) Reduction in coal consumption (from 0.77 to 0.553 kg/KWH in trial).

iii) Reduction in auxilliary power consumption (1.5% in trial).

iv) Reduction in outage/downtime of coal mills due to absence of foreign material. This helps in avoiding frequent load reductions.

v) Reduction/elemination of fuel oil support.

vi) Reduction in furnace wall slagging, boiler tuble leakages, clinker formation, abnormal erosion etc.

vii) Improvement in boiler efficiency (2% in trial).

viii) Reduced smoke and dust emission.

ix) Reduced running maintenance on the boilers and its auxilliaries.

x) Reduced ash generation and consequent reduction in the ash disposal area.

In view of above mentioned advantages and as pre-requisite for control of pollution, the thermal power plants, should use beneficiated coal.

(Action : Department of Coal/Ministry of Energy/State Electricity Boards)

Management Techniques of Wasteland Afforestation

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Abstract

Wastelands are primarily formed due to misuse or overuse. Lack of any management is responsible for their degradation. The degree of degradation will determine the technique of afforestation. Soil conservation measures may be additionally necessary for any afforestation activity. The agencies responsible for formation of wastelands need to be controlled. Climatic conditions are generally favourable for plant growth in India. Excessive grazing, lopping, humus removal and fires are the major factors that prevent natural rehabilitation of such sites. The soil structure is an important consideration in the choice of species and techniques of afforestation. Wastelands are not productive lands. Afforestation may not be financially viable in short rotations. Nature rehabilitates sites through recycling of nutrients. Every vegetation contributes to site amelioration. Early removal of establishing vegetation is harmful for the afforestation of sites. Grazing and lopping must be controlled. Matching species to sites is essential. The juvenile growth in trees is not generally related to adult growth. Early flowering is an indicator of the unsuitability of a species to the site. Suitable management systems will need to be developed so that the sites do not degrade by harvesting. Complete removal of tree cover may not be desirable at any stage of management.

Introduction

About one-third of the land area in India is losing its productivity at a fast pace due to serious environmental problems. These lands are, however, overused for grazing and firewood collection. Both the degree of degradation and the extent of such lands is increasing. Afforestation of these lands is the most cost effective ~~method~~ of reclaiming these lands (Chaturvedi 1983,1985). Afforestation of these lands needs high degree of technical skill. The edapho-climatic conditions vary a great deal. The methods of soil working will vary accordingly. The matching of species to sites is a major technical decision (Troup 1921). In some cases, some species not really suitable to the site establish during the juvenile phase and fail subsequently. Site species trials are, therefore, essential to know what species should be planted.

Rural areas depend mainly on agricultural wastes, animal residues and fuelwood for their energy needs. Agricultural wastes are increasingly becoming in short supply because several of these are finding industrial uses such as paper making, activated charcoal etc. Amongst the animal residues cow dung cakes are a very important source of energy. The biogas programme which converts the animal residue to gas and the rest as fertilizers has limited application because of the minimum economics of scale. Only some well to do farmers are able to set up *gobar* gas plant. Large majority of our rural people are still dependent on fuelwood. Fuelwood is a renewable source of energy so long as the sites in which trees grow are not over exploited (Gustafa Sieun 1982) Unfortunately most lands in India have been misused for several decades and in some cases for several centuries. Wherever, the population pressure has been high, the forests have disappeared (FAO 1964). All the ancient places in India like *Mathura, Ayodhya, Hastinapur* etc. are areas of zero forests. This has been the history of all ancient civilizations. Forests have always been considered as limitless till they disappear.

In the tropical climate, destruction of forests adversely affects the soils and the general climate. The micro flora of the site is killed by strong sun. the soil erodes both by wind and rain. The organic matter is soon lost and reduced fertility increases the grazing pressure. The reduction of the tree cover reduces the atmospheric moisture and consequently, the precipitation also gets reduced. The precipitation in any area is composed of two parts. One which is contributed by the monsoon which is obtained from sea. The second part consists of the local water vapour which precipitates. It is this local moisture which is contributed by the transpiration of a large number of trees. Individual trees seldom contribute to the change in the rainfall patterns but the extended forest areas always significantly contribute to rainfall. Studies carried out in Ethiopia and elsewhere have shown that the contribution of the transpired moisture can be as high as 40% of the total precipitation in the area. The difference in the rainfall of the erstwhile afforested districts clearly shows that the average rainfall and the number of rainy days are much less after the deforestation. In Panchmahal district of Gujarat bordering Madhya Pradesh and Rajasthan, heavy deforestation has affected rainfall. It rained 1,872 mm in 1976-77, 1,051 mm in 1980-81, 511 mm in 1986-87 and 437 mm in 1987-88 (Gupta 1988). A record of rainfall data of other erstwhile forested districts will show the same grim picture. Much of the land available in India is degraded. It is low in fertility and the reduced rainfall has further decreased production.

Nutrient Recycling

Trees have a system of recycling nutrients. The major recycling is done through the decomposition of leaves and the decay of the roots. This recycling is related to tree growth. In the initial stages of fast growth of trees, the recycling of nutrients is much less than their uptake. Consequently the trees do not improve sites during their fast phase of growth. When the period of fast growth is passed, the recycling of nutrients is much more than the uptake. Consequently, the sites improve only when trees are kept on a site beyond their fast rate of growth. The shortage of wood has pushed up prices of all wood products. There is a tremendous shortage of wood for the paper industry and for plywood, match wood etc. Several committees have worked out the expected annual demand of firewood in the year 2000 to be of the order of 130 million tonnes. The demand of firewood, exceeds all other demand of wood. The production of 130 million tonnes of firewood needs an area of 80 million hectares on the basis of mean annual increment of 1.6 tonnes/ha/year. Such large areas may never be available for the production of firewood. Consequently, firewood is likely to remain in short supply in the foreseeable future. Firewood will, therefore, have a ready market for a long time to come. Many times it is very difficult to distinguish between the pulpwood and firewood. The same type of wood can be used as both. This diversion of firewood for industrial use has been beneficial in increasing the market price of wood. The increased rates of wood has made tree farming a profitable business. India has a very rich flora. There are large number of tree species which are reasonably good firewoods. The burning quality of wood of any species changes with age. A very young tree has a lower density and consequently, this wood burns fast. There is not a large difference in the calorific values of wood but the other burning properties like density and smoke vary considerably with species. The young trees have higher moisture content than the old ones. Consequently, wood from the young trees can not be considered in the same class as wood from older trees. Tree species reach their maximum density at different ages. The burning properties reach their optimum age when highest density is reached. In the market such wood fetches a higher price than wood of lower density.

Trees and Soil Fertility

Nitrogen fixing trees are generally considered to improve the soil fertility. The improvement in fertility takes place primarily from the decomposition of leaves. Leaves are the primary appendages of trees for photosynthesis which produces sugar. This sugar is converted into cellulose, the major component of wood. The history of forests of India will show that large areas of forests have been destroyed through incessant lopping and grazing. Most nitrogen fixing trees are heavy seeders. They consume most of the nitrogen that they fix through root nodules in this process. In addition, they draw lot of phosphorus also from the soil. Considerable part of this nitrogen is also deposited in the leaves. Leaves are, therefore, the major component of the improvement of soil. If leaves are lopped for fodder or other wise removed, the sites are likely to deteriorate in their nutrient status. Simultaneously, the tree growth also will be reduced because of the reduced photosynthetic activity. It should be noted that every part of the tree contributes in transpiration while photosynthesis activity is carried out by leaves and other green parts only. Consequently, in trees which are lopped for fodder, the tree reserve is used up in transpiration, such trees ultimately die much before their normal age. Apart from the root nodules, trees have several other methods of utilising the nitrogen from the atmosphere. The microflora, specially bacteria play a very significant role in providing these nutrients to the trees (Gordon and Wheeler 1983).

Tree Improvement

-The genetic component of the trees is generally not given the importance that it deserves. Trees are attacked by insects and fungi during every period of their growth. Trees have in-built capacity to fight these adverse conditions. Primarily the trees develop resistance to these external enemies through a wide genetic base. Trees which are cross pollinated produce plants which combine the characteristics of several trees. Even amongst trees of same species every tree is not alike, they differ in several components. One aspect which can be clearly analysed is the alkaloid content of leaves and other tissues. These vary from tree to tree. Where the genetic base of trees is very narrow, the risk of trees being attacked multiply manifold. Ignorance of this aspect of the tree can create catastrophe as has happened with the plantations of *Leucaena leucocephala* in Philippines. The Psyllid (jumping lice) which finished all plantations of *Ipil Ipil (Subabul)* in Philippines, Indonesia, Sri Lanka etc. were plants of a very narrow genetic base and there was no possibility of their success. Where manipulated hybrids are used for plantations, it is necessary to produce new hybrids from naturally growing trees very frequently otherwise they suffer from some disease or some pests before they can reach harvestable age. Plants which are raised by clonal propagation have even greater risk than those raised from seeds. The problem is more serious in case of species with high degree of self pollination (Eldridge 1983).

Seedling Establishment

Normally the mortality in new introduced tree in an area may not take place during the first few years of its planting. The interaction of sites and trees starts later in life, usually about 3 to 4 years after planting. Where tree species are not matched to site, they either die or stagnate after this period. Consequently, suitability of any species to a new site cannot be judged earlier than the expected period of rotation of maximum volume production. One must, therefore, be very cautious in choosing a new species at a site. The controversy of an exotic or indigenous tree species is irrelevant. Several times the exotic species may do better than the indigenous tree species that grew there long time ago. One must realise that the edapho climatic conditions in any locality are not stable. They change, consequently, the species that is likely to grow well in the changed conditions may be very different than what grew there sometime ago. The judgement how and why a particular tree species does well depends on a large number of factors which are not easy to identify. The ultimate success depends only through good experimentation carried out over a long period. It is of the utmost importance that R & D investment in fuelwood trees and shrubs on various kinds of wastelands, land management and soil conservation methodologies should be strengthened. Adequate emphasis must also be laid on the correct provenance and quality of seeds to match with the planting sites. While choosing the species for plantation, it should be ensured that the agencies responsible for destruction of forests can be controlled. The productivity from a forest plantation depends on the interaction of the genetics of the trees and the environment. High productivity cannot be obtained on lands of low fertility. Unusually high or low temperatures may also limit the growth. Atmospheric humidity can considerably affect the rates of growth. Generally plantations of single species are more productive than a mixture of species. Where edaphic conditions are variable, a situation which is prevalent in most degraded lands in India, several species will need to be planted according to the depth as well as physical and chemical components of the soil. The mixing of these species may be in blocks or along contours. A mixture of a large number of tree species cannot ensure success. A species that coppices well is a desirable species in firewood farming as it ensures better economics and ready replacement for unintentional damage. Most of our lands are under heavy pressure of grazing. Cost of protection of a species that is a good fodder will be more than a tree with a built in protection mechanism like a thorn, acrid juice or a non-palatable leaf. No tree species can grow every where specially in India where edapho climatic conditions vary a great deal (Seth 1951).

Some of the species that can be suggested for planting on wastelands are:

a) Water Logged Sites

Legerstroemia flosreginae, Sapium sebiferum Syzigium cumini, Terminalia arjuna

b) Ravinous Tracts

Acacia nilotica, Azadirachta indica, Prosopis juliflora, Haplophragma adenophyllum, Cassia siamea, Albizia lebbeck, Dendrocalamus strictus, Adhatoa vasica, Cassia auriculata, Holoptelia integrifolia, Lannea gradis, Dalbergia sissoo, Eulaliopsis binata

c) Areas of Brackish Water

Cordia dichotoma, Pongamia pinnata, Cassia siamea, Haplophragma adenophyllum, Prosopis juliflora, Acacia nilotica.

d) Dry Tracts

Butea frondosa, Prosopis juliflora, Albizia amara, Anogeissus pendula, Prosopis cineraria, Techomella undulata, Dichrostachys cineria, Capparis decidua, Diospyros melanoxylon, Pterocarpus marsupium, Cassia siamea, madhuca latifolia, Ailanthus excelsa, Azadirachta indica, Hardwickia binata, Anacardium occidentale, Acacia senegal, A. tortilis.

e) Foot Hills

Coraria nepalensis, Acacia mearnsii, Pinus roxburghii, Salix spp., Alnus nitida, Rhus continus, Cedrela toona, Quercus serrata, Jasminum spp., Haplophragma adenophyllum, Garuga pinnata.

f) Usar (Saline-alkaline) Sites

Prosopis juliflora, Acacia niotica, Terminalia arjuna, Pongamia pinnata, Populus deltoides, Albizia lebbeck, Acacia leucophloea, Haplophragma adenophyllum, Cassia siamea, Dendrocalamus strictus, Syzigium cumini, Salvadora persica, Casuariana equisetifolia (in non-frosty areas).

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